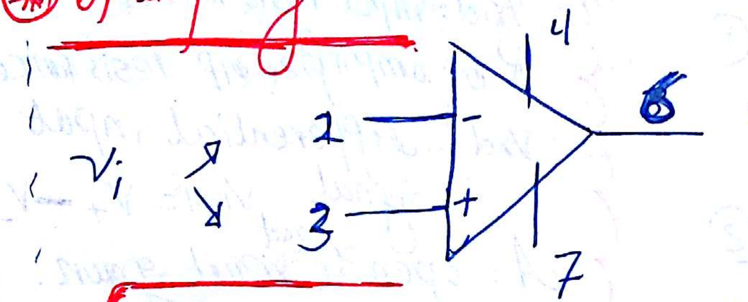
Sec # (1)

operational amplifier

operational amplifier هو نوع أشهر من ال amplifier

op-Amp
- → op.amp symbol
- → " " model
- → " " types

op amp symbols



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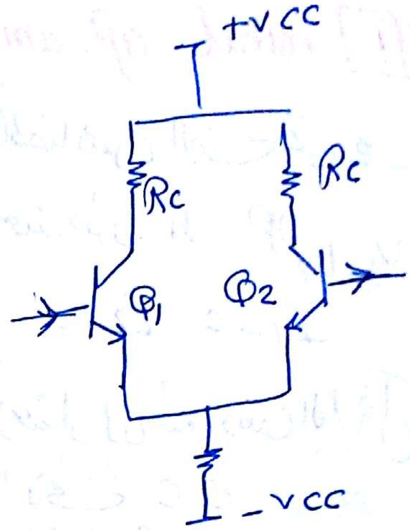
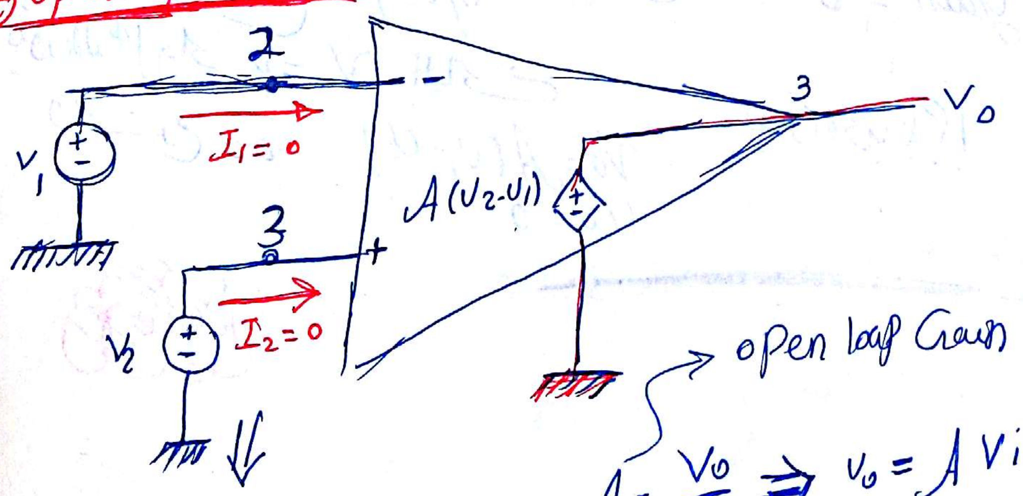


op amp - Terminals

- (2) is inverting i/p Terminal
- (3) is noninverting " "
- (6) for the o/p signal
- (7) for positive DC power supply
- (4) for negative DC power supply

op-amp model



model
في حالة وجود
source + Load
في الورقة التالية

open loop Gain

$V_i = V_2 - V_1$

$A = \frac{V_o}{V_i} \Rightarrow V_o = A V_i$

$V_o = A(V_2 - V_1)$

من الشكل السابق يتضح أن ال op amp يكبر الفرق في i/p signals وليس ال i/p signal لذلك يسمى

*Note (1) differential op-amp ..

1

types of op-amps

ideal op-amp ← → non-ideal op-amp

[1] ideal op-amp

وهناك بعض الخصائص التي تميزه

1) لا يمر تيار عند طرفي الـ i/p v_1, v_2

$I_1 = 0 \quad I_2 = 0$

2) لذلك يمكن اعتبار أن مقاومة الدخل كبيرة جدا "∞" زي O.C

∴ input impedance of ideal amplifier = ∞

3) o/p impedance of ideal amplifier = 0

ودى ميزة

4) A (open loop gain) of ideal amplifier = ∞ $\quad V_o = A(V_2 - V_1)$

$10^3, 10^4$ —

Common-mode Gain = 0 ⑥

يعني ايه ؟!؟!

5) Band width = ∞

والمقصود بيه

هو الـ Gain بتاع الـ op-amp لما يكون الدخل على $V_+ = V_-$ بالتالى الخرج = 0

$V_o = A(V_+ - V_-)$

$V_o = 0$

Note

parameters خواص بتيجي في data sheet

Rid: input resistance.

Ro: amplifier o/p resistance

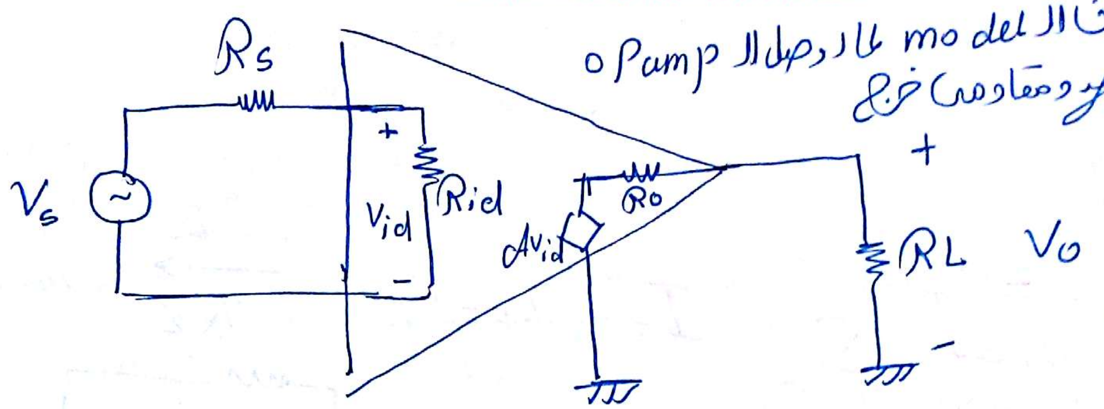
Vid: differential input signal $\quad Vid = V_+ - V_-$

A: open load circuit gain.

الـ Gain العادى من غير أى توصيل

Note

اشوف ال model للدوائل oPamp
مصدر جهد ومقاومة خرج &



$\underline{A_v}$ overall gain

$$A_v = \frac{V_o}{V_s} = \frac{V_o}{V_s} * \frac{V_{id}}{V_{id}}$$

$$A_V = \frac{V_o}{V_{id}} * \frac{V_{id}}{V_s}$$

$$\cancel{V_o = A V_{id} \cdot \frac{R_{id}}{R_{id}+R_s}}$$

$$\cancel{V_o = A * V_{id} *}$$

$$A_V = A V_{id} \frac{R_L}{R_L+R_o} \cdot \frac{R_L}{R_L+R_o}$$

- $V_{id} = V_s * \frac{R_{id}}{R_{id}+R_s}$

$$\frac{V_{id}}{V_s} = \frac{R_{id}}{R_{id}+R_s}$$

- $V_o = A V_{id} \times \frac{R_L}{R_L+R_o}$

$$\frac{V_o}{AV_{id}} = \frac{R_L}{R_L+R_o}$$

Note

لايجاد R_{in} ← $R_{in} = \frac{V_i}{i_s}$ عند ال input port

لايجاد R_o ← $R_o = \frac{V_x}{i_x}$ عند ال o/p port

$\underline{V_{in} = 0}$ &

لايجاد A_v

الدوائر محتاج اعمل analysis

مثال

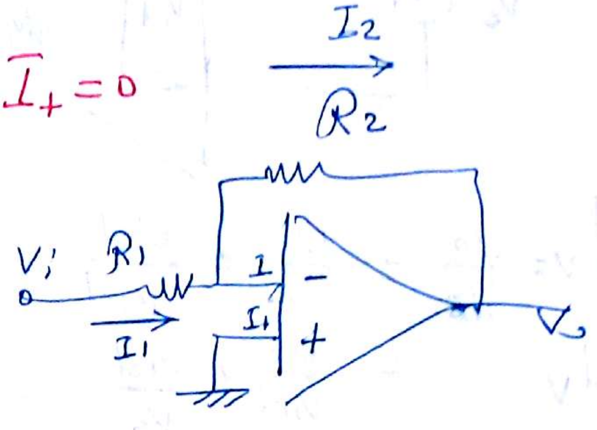
2+

$V_- = V_+$

$V_+ = 0$

$V_- = 0$

& $I_- = I_+ = 0$



"inverting opamp"

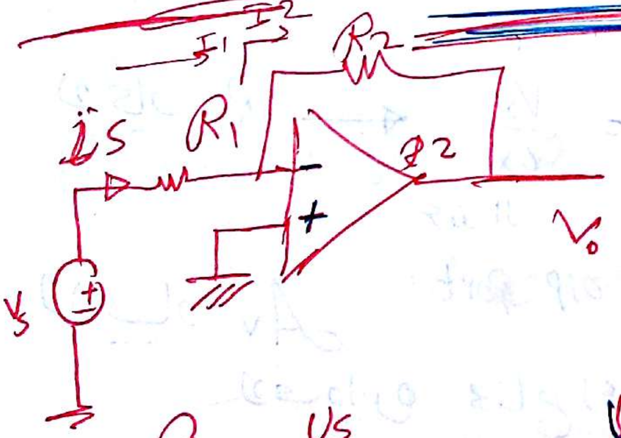
$I_1 = I_2$

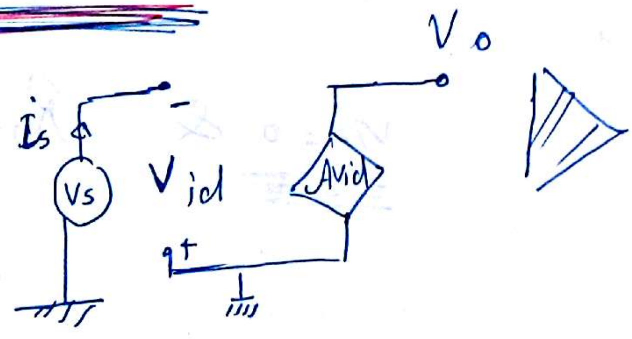
$$\frac{V_s - \cancel{V_-}}{R_1} = \frac{\cancel{V_-} - V_o}{R_2}$$

$$\frac{V_s}{R_1} = \frac{-V_o}{R_2}$$

$$V_o = -\frac{R_2}{R_1} V_s \quad \#$$

$$\boxed{A = -\frac{R_2}{R_1}}$$



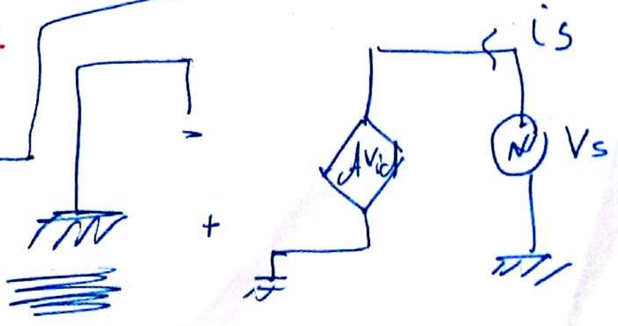


$$R_{in} = \frac{V_s}{i_s}$$

$V_- = V_+ = 0$

$$I_s = I_1 = I_2 = \frac{V_s}{R_1}$$

$R_{in} = R_1$



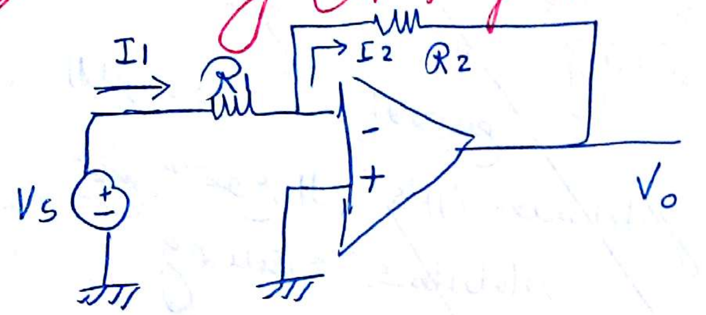
$R_{out} = 0$

5

ideal . op.amp انواع ال

في كل نوع هاتجيب R_o, R_{in}, A_v

a) inverting Amplifier



• يسمى النوع ده inverting لان الدخل على الطرف السالب للـ op.amp
وبالتالى فيه phase shift بين o/p & i/p = 180°

• لايجاد الـ R_{in} احط مصدر V_s بيطلع i_s
$R_{in} = \frac{V_s}{i_s}$

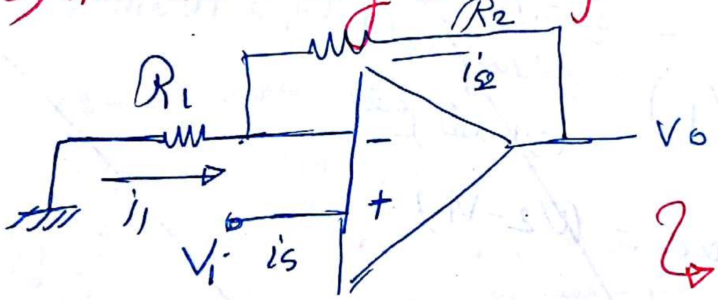
• لايجاد الـ R_o احط V_x بيطلع i_x & $V_s = 0$
$R_o = \frac{V_x}{i_x}$

$$A_v = -\frac{R_2}{R_1} \quad \#$$

$$R_{in} = \frac{V_s}{I_s} = R_1 \quad \#$$

$$R_{out} = \frac{V_x}{i_x} = 0 \quad \#$$

b) non inverting Amplifier



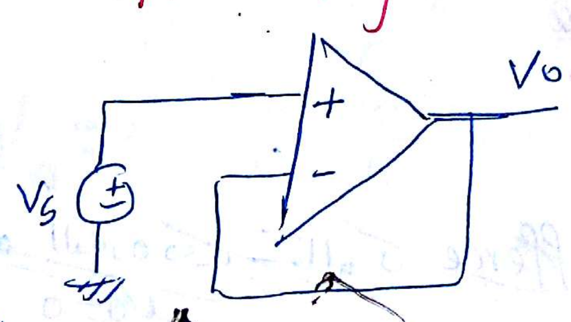
• يسمى النوع ده non-inverting لان الخرج سيخرج هو هو الدخل inphase مع بعض

$$A_v = \left(1 + \frac{R_2}{R_1}\right) \quad \#$$

$$R_{in} = \frac{V_i}{i_s} = \infty \quad i_- = 0 \quad \#$$

$$R_o = \frac{V_x}{i_x} = 0 \quad \#$$

c) Buffer amplifier or unity Gain Buffer or voltage follower



$\frac{V_s}{i_s} = \quad V_s = V_-$
$V_- = V_+$
$i_+ = 0$
$V_s = 0$
$R_o = 0$

الدايره دى هى b) ولكن
$R_1 = \infty$
$R_2 = 0$

$$A_v = 1 + \frac{0}{\infty} = 1 \quad \#$$

i_s
$i_s = I_+ = 0$
$R_{in} = \infty$

$$R_{in} = \infty \quad \#$$
$$R_o = 0$$

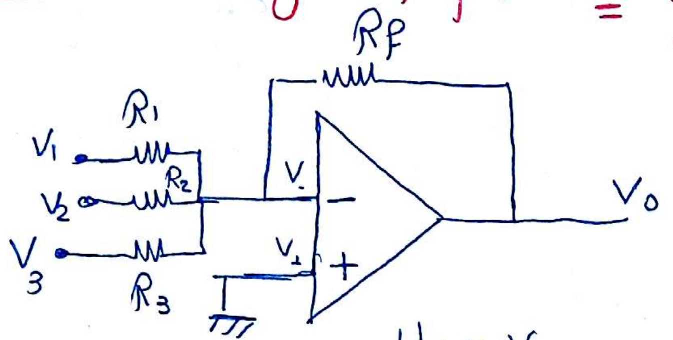
وبكده الدايره دى تعتبر

$A_v = 1$ + Very high i/p R + Very low o/p R

لذالك تستخدم كـ Buffer

Sec #(2)
operational amplifier

[d] Summing amplifier or weighted summing
scalling summing.



• الدايره دى بتشيل مجموع ال iIPs بس بعد ماأعمل لها scalling الاول

$V_+ = V_-$

هـ بتجمع ال iIPs معمولها scalling :.

$$V_o = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3 \right)$$

$\frac{R_f}{R_1}$ ≡ scale for i/p signal ①

$\frac{R_f}{R_2}$ ≡ scale for i/p ②

$\frac{R_f}{R_3}$ ≡ scale for i/p ③

• ال scale دى اقدر أتحكم فيها زى ماناعاوز

exp

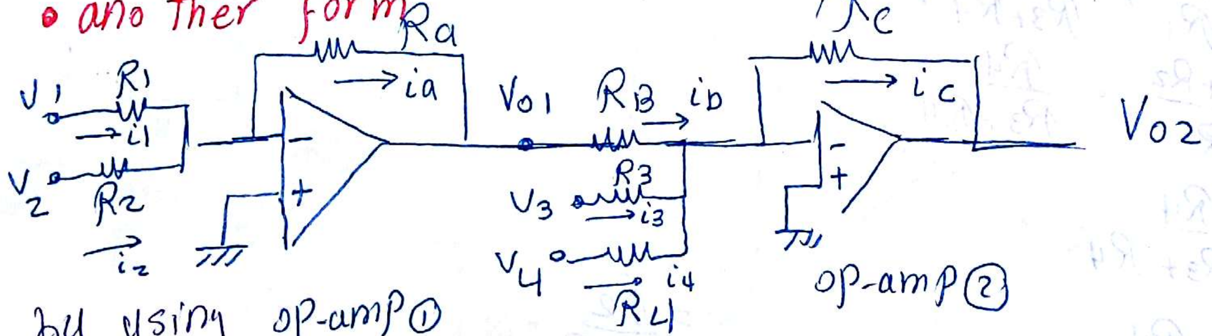
if $R_1 = R_f = R_2 = R_3$

$\therefore V_o = -(V_1 + V_2 + V_3)$

problem (8)
problem (7) > Summing.

~~[C] difference amplifier~~

• another form



by using op-amp ①

super position

$$V_{o_1} = -\left[\frac{R_a}{R_1} V_1 + \frac{R_a}{R_2} V_2 \right] \quad ①$$

بالتعويض

$$V_{o_2} = -\left[\frac{R_c}{R_b} V_{o_1} + \frac{R_c}{R_3} V_3 + \frac{R_c}{R_4} V_4 \right] \quad ②$$

$$V_o = V_{o2} = \frac{R_c}{R_b} \frac{R_a}{R_1} V_1 + \frac{R_c}{R_b} \frac{R_a}{R_2} V_2 - \frac{R_c}{R_3} V_3 - \frac{R_c}{R_4} V_4 \quad \#$$

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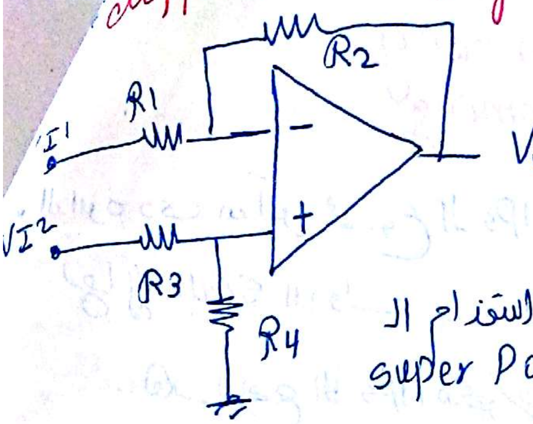
difference amplifier

٥ تستخدم هذه الدايره لتكبير الفرق بين إشارتين

بعد scaling



تم استخدام ال super position

• $V_{I1} = V$, $V_{I2} = 0$ $\Rightarrow$ $V_{o1} = -\frac{R_2}{R_1} V_{I1}$

• $V_{I1} = 0$, $V_{I2} = V$ $\Rightarrow$ $V_{o2} = \left(1 + \frac{R_2}{R_1}\right) V_+$

$$V_{o2} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)$$

$$V_o = -\frac{R_2}{R_1} V_{I1} + V_{I2} \left(1 + \frac{R_2}{R_1}\right) \frac{R_4}{R_3 + R_4} \quad \#$$

Note

لكى تعمل هذه الدايره ك difference between Two i/ps signal $\Leftarrow$ لازم يتحقق الشرط ٥

$$\frac{R_2}{R_1} = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)$$

$$\frac{R_2}{\cancel{R_1}} = \frac{R_1 + R_2}{\cancel{R_1}} \cdot \frac{R_4}{R_3 + R_4} =$$

$$\frac{R_2}{R_1 + R_2} = \frac{R_4}{R_3 + R_4}$$

لازم $\frac{R_2}{R_1} = \frac{R_4}{R_3}$

$$\therefore V_o = -\frac{R_2}{R_1} V_{I1} + \frac{R_1 + R_2}{R_1} \times \underbrace{\left(\frac{R_4}{R_3 + R_4}\right)}_{= \frac{R_2}{R_1 + R_2}} V_{I2}$$

$$V_o = -\frac{R_2}{R_1} V_{I1} + \frac{\cancel{R_1 + R_2}}{R_1} \times \frac{R_2}{\cancel{R_1 + R_2}} V_{I2}$$

$$V_o = \frac{R_2}{R_1} [\underbrace{V_{I2} - V_{I1}}_{V_{Id}}] \quad \#$$

if $R_2 = R_1$

$$V_o = V_{I2} - V_{I1} = V_{Id} \quad \#$$

→ problem (13)

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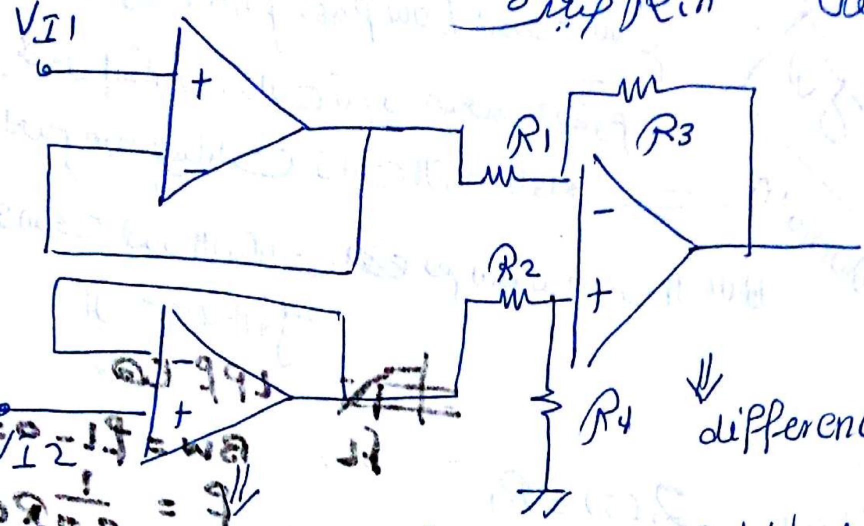
E) instrumentation amplifier

تستخدم هذه الدايره ايضاً لتكبير الفرق بين اشارتين

وذلك لان عيب الدايره السابقه R_{in} صغيره

فيقدم حل هذه المشكله



بهذه الدايره

أي ادخال ال i/ps على follower الاول

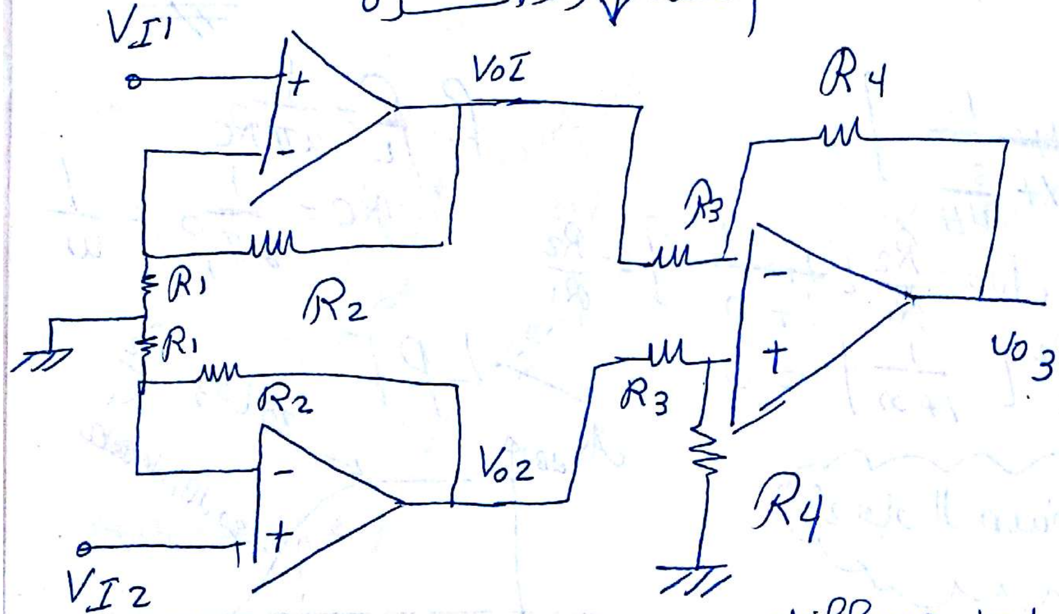
difference amplifier

Voltage follower يتم استخدامها لحل هذه المشكله وبالتالي R_{in} ↑↑

$R_{in} = \infty$

ولكن عيبها ان $A_v = 1$

لذلك نستخدم هذه الدايره



$$V_{o1} = V_{I1}\left(1+\frac{R_2}{R_1}\right)$$

$$V_{o2} = V_{I2}\left(1+\frac{R_2}{R_1}\right)$$

$$V_{o3} = \frac{R_4}{R_3}\left[V_{o2}-V_{o1}\right]$$

$$V_o = \frac{R_4}{R_3}\left[1+\frac{R_2}{R_1}\right]\underbrace{\left[V_{I2}-V_{I1}\right]}_{V_{Id}} \quad \#$$

∴ هذه الدايره تقوم بعمل difference علي

و R_{in} ↑↑

و A اصبح كبيره

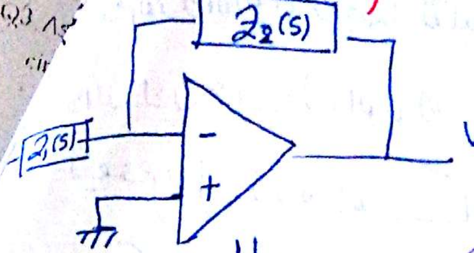
ولكن

عيب هذه الدايره

- A_1, A_2 should be perfectly matching
- To varid A_d Two R have to be varid simulatous في أن واحد

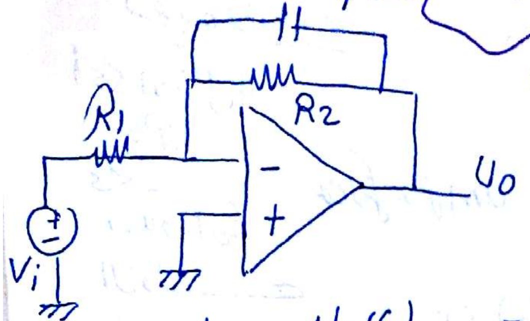
Active low Pass filter

يعني ايه LPF ؟؟



$\Downarrow$ $1/SC$

$S = j\omega$ s domain



في هذا النوع من الـ op-amp نقوم باستخدام كأنك دايره Low pass filter بحيث يسمح بمرور إشارات ذات تردد صغير ويقوم بعدم مرور الإشارات ذات التردد العالي ومدى هذه الاشارات التي يتم تحديده من الـ B.W الـ filter

هو LPF

f_L

$BW = f_L - 0 = f_L$

$f = \frac{1}{2\pi RC}$

$\uparrow RC \rightarrow BW \downarrow$

$$A_v = \frac{V_o(s)}{V_i(s)} = -\frac{Z_2(s)}{Z_1(s)} \qquad Z_1(s) = R_1 \qquad Z_2(s) = \frac{1}{sC} \parallel R_2$$

$$A_v = -\frac{\frac{1}{sC} \times R_2}{\frac{1}{sC} + R_2} \times \frac{1}{R_1} = -\frac{R_2}{sCR_2+1} \times \frac{1}{R_1} = -\frac{R_2}{R_1}\,\frac{1}{sCR_2+1}$$

$$A_v = -\frac{R_2}{R_1}\left[\frac{1}{1+\frac{s}{\omega_H}}\right]$$

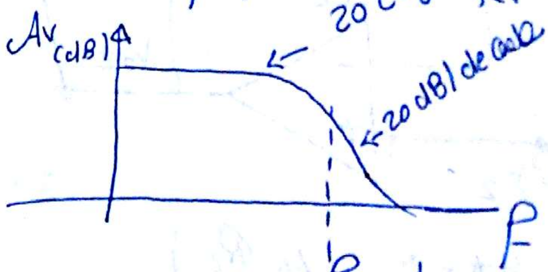
$$f_H = f_L = \frac{1}{2\pi RC} \qquad RC = \frac{1}{2\pi f} = \frac{1}{\omega}$$

$S = 0$ $\quad A_v = -\frac{R_2}{R_1}\left[\frac{1}{1+0}\right] = -\frac{R_2}{R_1}$

$S = \infty$ $\quad A_v = -\frac{R_2}{R_1}\left[\frac{1}{1+\infty}\right] = 0$

$\Rightarrow$ LPF

لايجاد الـ Gain عند اي تردد



$f_c = \frac{1}{2\pi RC}$

$A_{v\,mid} = \frac{R_2}{R_1}$

$$\left|\frac{V_o}{V_{in}}\right| = \frac{\frac{R_2}{R_1}}{\sqrt{1+\omega^2C^2R_2^2}} \longleftarrow \text{مقدار}$$

$$\phi = 0 - \tan^{-1}\omega C R_2 \longleftarrow \text{الزاوية}$$

$\hookrightarrow$ problem (12)

$A_v = -\frac{R_2}{R_1}$ midrange

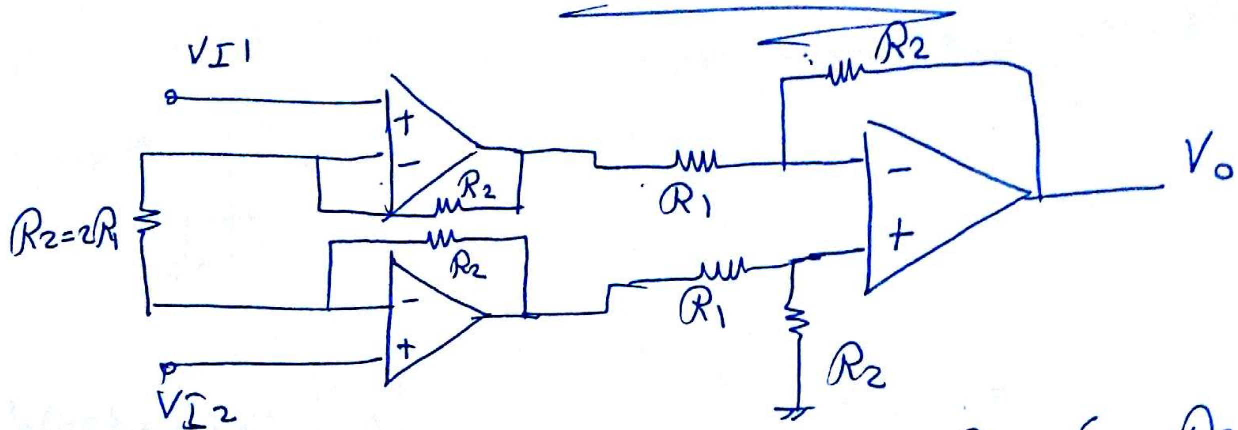
f_c عند اي تردد $< A_{vm}$

$A_v = \frac{V_o}{V_i} = \frac{Z_2}{Z_1}$

$Z_2 = \frac{1}{sC} \parallel R_2 \qquad Z_1 = R_1 \qquad S = j\omega$

4

حل هذه المسألة



$$V_o = -\frac{R_4}{R_3}\left[1+\frac{R_2}{R_1}\right]\left[V_1-V_2\right]$$

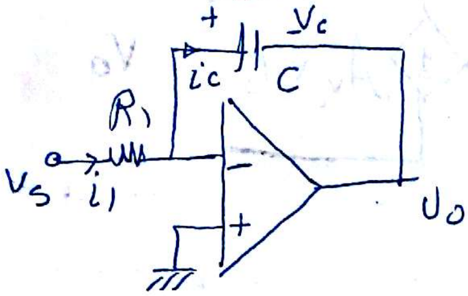
analysis الدوائر في الامتحان

في كل حالة إيجاد A_v & R_o & R_{in} في الامتحان

problem (14)

[h] The integrator

الجزء سوف نقوم بالتعرف
في الدايره التي تقوم بعمل عمليه التكامل للدخل



$$i_c = C\frac{dV_c}{dt}$$

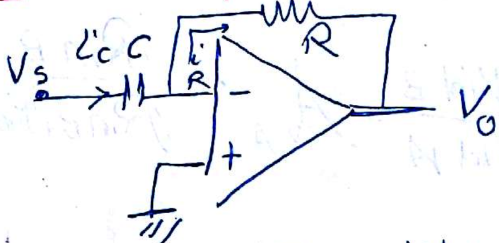
$RC = \tau$ Time Constance

$$V_o(t) = -\frac{1}{RC}\int V_s(t)\,dt + V_o(0)$$

$\underline{=} \rightarrow$ الشحن الابتدائي على المكثف

↳ problem (8) و (9)

[I] The Differentiator

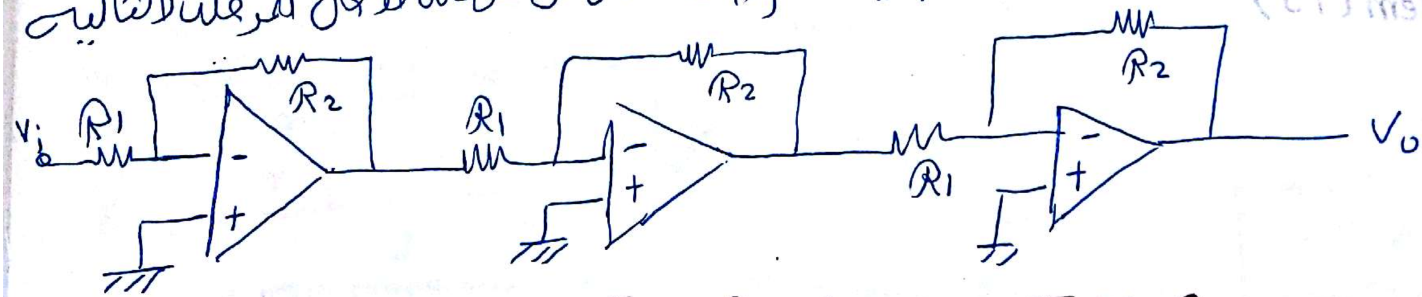


$$V_o = -RC\frac{dV_s}{dt}$$

↳ problem (10), (11)

Cascaded Amplifier

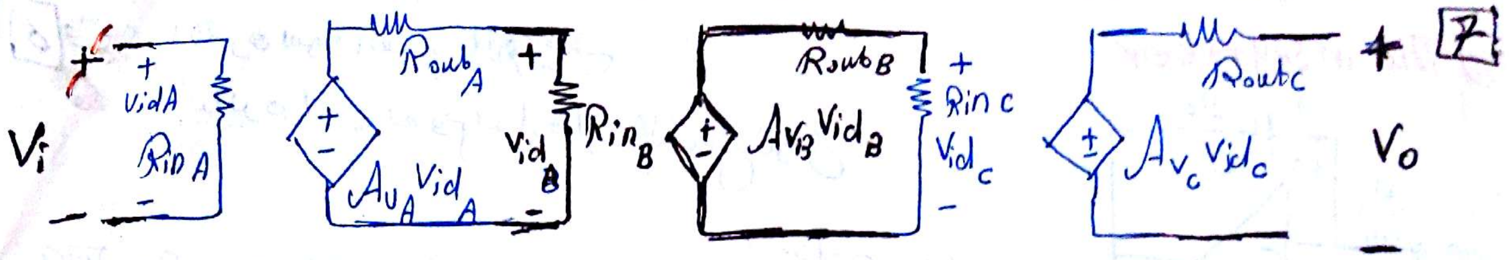
في هذا الجزء سوف نقوم بالتعرف على كيفية الحصول على ال gain الخاص بتوصيل أكثر من مرحلة لل op amp مع بعض بحيث يتم أخذ خرج كل مرحلة كدخل للمرحلة التالية



المراد إيجاد R_o, R_{in}, A_v

$R_{in} = R_{in\,a}$

$R_o = R_{o\,C} = 0$



$$A_v = \frac{V_o}{V_i} = \frac{V_o}{V_{idc}} \times \frac{V_{idc}}{V_{idB}} \cdot \frac{V_{idB}}{V_{idA}} \cdot \frac{V_{idA}}{V_i}$$

$$V_o = A_{v_c} V_{idc} \rightarrow \frac{V_o}{V_{idc}} = A_{v_c}$$

$$V_{idC} = A_{v_B} V_{idB} \times \frac{R_{inc}}{R_{inc} + R_{outB}} \longrightarrow \frac{V_{idc}}{V_{idB}} = A_{v_B} \cdot \frac{R_{inC}}{R_{inc} + R_{outB}}$$

$$V_{idB} = A_{v_A} V_{idA} \times \frac{R_{inB}}{R_{inB} + R_{outA}} \rightarrow \frac{V_{idB}}{V_{idA}} = A_{vA} \cdot \frac{R_{inB}}{R_{inB} + R_{outA}}$$

$$V_{idA} = V_{in} \times \frac{R_{inA}}{R_{inA} + 0} \Rightarrow V_{idA} = V_{in}$$

$$A_v = A_{vA} \cdot \frac{R_{inB}}{R_{inB} + R_{outA}} \cdot A_{vB} \cdot \frac{R_{inC}}{R_{inC} + R_{oB}} \cdot A_{vC} \cancel{=} 1$$

problem (15)

Sec 2

Sheet #3
(Operational Amplifier)

Q1. A differential amplifier has R_s=5kΩ, and R_L=1KΩ:

a) Find the overall voltage gain A_v of the amplifier,

b) What is the amplitude of v_s of the sinusoidal input signal needed to develop a $10V_{p\text{-}p}$ at the output terminals?

(Consider R_{id}=1MΩ, R_o=0.5Ω, and A=60dB)

Q2. Suppose a differential amplifier has A=100dB, and it is operating in a circuit with a circuit output voltage of V_o=15V. What is the input voltage V_{id} and how large must be the voltage gain to make $V_{id} \le 1\mu V$? What is the input current i_i if R_{id}=1MΩ?

Q3. Assuming ideal op amps, find the voltage gain V_o/V_i, R_{in} and R_o of each f the circuits of Fig.P3.

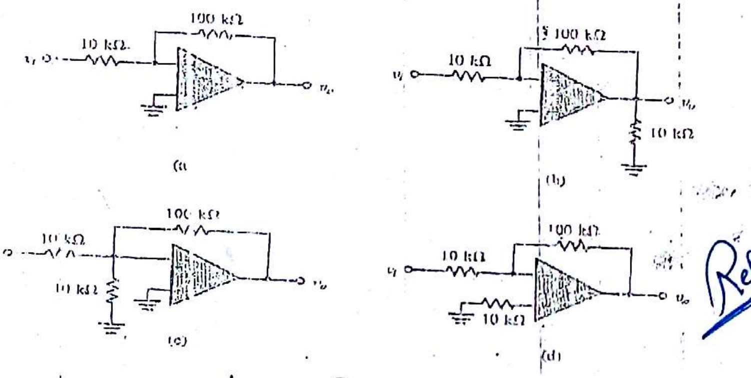


Fig.P3

Report

inverting

Q4. (Report) Find the voltage gain, input resistance, and output resistance of the amplifier shown in Fig.P4 if R_1=4.7KΩ R_f=220KΩ. Express the voltage gain in dB. deciBell

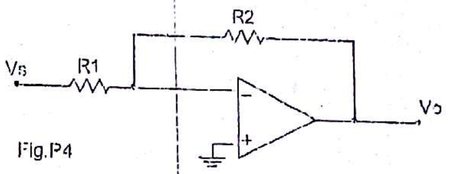


Fig.P4

non inverting

Q5. Find the voltage gain, input resistance, and output resistance of the amplifier shown in Fig.P5 if R_1=8.2KΩ, R_2=680KΩ. Express the voltage gain in dB.

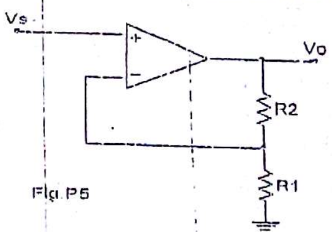


Fig.P5

Inverting Summing

Q6. Write an expression for the output voltage $v_o(t)$ of the circuit shown on Fig.P6 if R_1=1KΩ, R_2=2KΩ, R_3= 51KΩ, $v_1(t)$ =0.01sin(3770t), and $v_2(t)$=0.04sin(10000t). Also write an expression for the voltage at the summing junction (v).

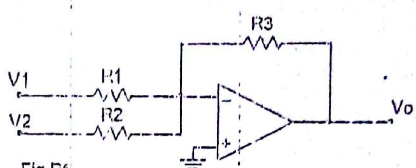


Fig.P6

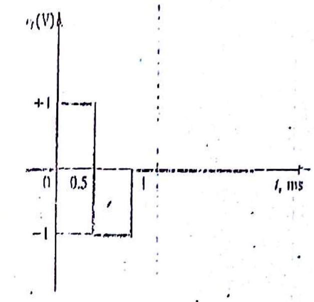
Summer

summing

Q7. Determine the values of i/p resistors required in a six-i/p scaling adder so that the lowest weighted i/p is 1 and each successive i/p has a weight twice the previous one (Use R_f= 100kΩ). State an application for this circuit.

ingrator

Q8. A Miller in integrator whose input and output voltages are initially zero and whose time constant is 1ms is driven by the signal shown. Sketch and label the output waveform that results. Indicate what happens if the input levels are ±2V, with the time constant the same (1ms) and with the time constant raised to 2ms.



ingrator

Q9. The input voltage to the integrator circuit shown in Fig P9 is given by $v_s(t)$=0.1sin(2000πt). What is the output voltage if R=10KΩ, C=.005μF, and $v_o(0)$=0.

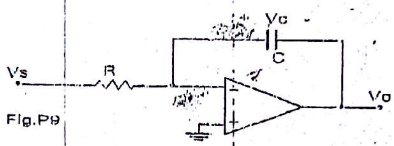
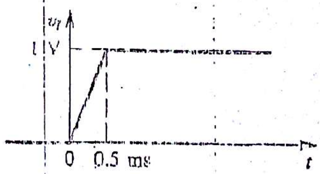


Fig.P9

differentiator

Q10. A differentiator utilizes an ideal op amp, a 10KΩ resistor and a 0.01μF capacitor. What is the frequency f_0 in Hz at which the input and output sine wave signals have equal magnitude? What is the output signal for a 1V peak to peak sine wave input with the frequency equal to $10f_0$?

Q11. (Report) An op amp differentiator with 1ms time constant is driven by the step shown. Assuming V_0 to be zero initially, sketch and label its waveform.



LPF

Q12. Design a low pass amplifier (i.e. Choose the values of R_1, R_2, and C) to have a frequency input resistors of 10KΩ, mid-band gain of 20dB and the bandwidth of 20 KHz.

M. Ileana

Q13. For the circuit shown in Fig.P13, use superposition to find V_0 in terms of V_1 and V_2. Find V_0 for:

$$v_1 = 10\sin(2\pi \times 60t) - 0.1\sin(2\pi \times 1000t), \text{ volts}$$
$$v_2 = 10\sin(2\pi \times 60t) + 0.1\sin(2\pi \times 1000t), \text{ volts}$$

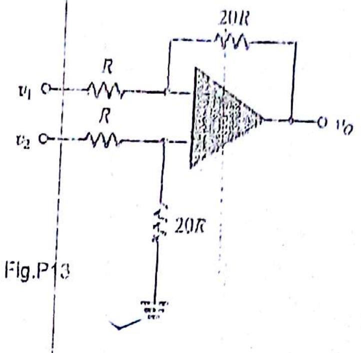


Fig.P13

instrument amplifier

Q14. What is the voltage of the instrumentation amplifier shown in Fig.P14, if R_1=1KΩ, R_2=100KΩ, R_3= 10KΩ, and R_4= 10KΩ. Write an expression for the output voltage $v_o(t)$ if $v_1(t) = 2+0.1\sin(2000\pi t)$, and v_2=2.1V.

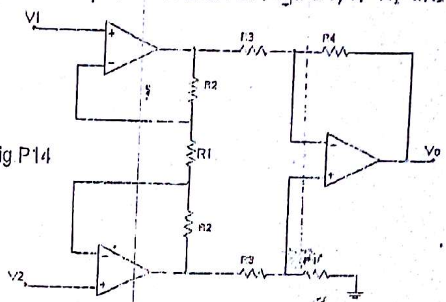


Fig P14

Cascaded

Report

Q15. An amplifier is formed by cascading op-amp stages as shown in Fig.P14:

a) Replace each op-amp circuit with its two representation model.
b) Use the circuit model of part (a) to find the overall A_v, R_{in}, and R_{out} for the complete three stage amplifier.
c) If the 2KΩ resistors are replaced with a value that gives an overall gain of 40dB. What is the new resistor value? What is the value of the new R_{in}?

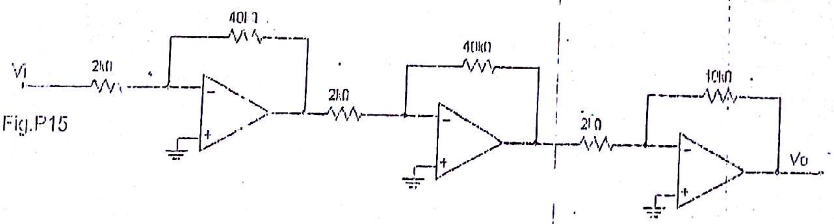


Fig.P15

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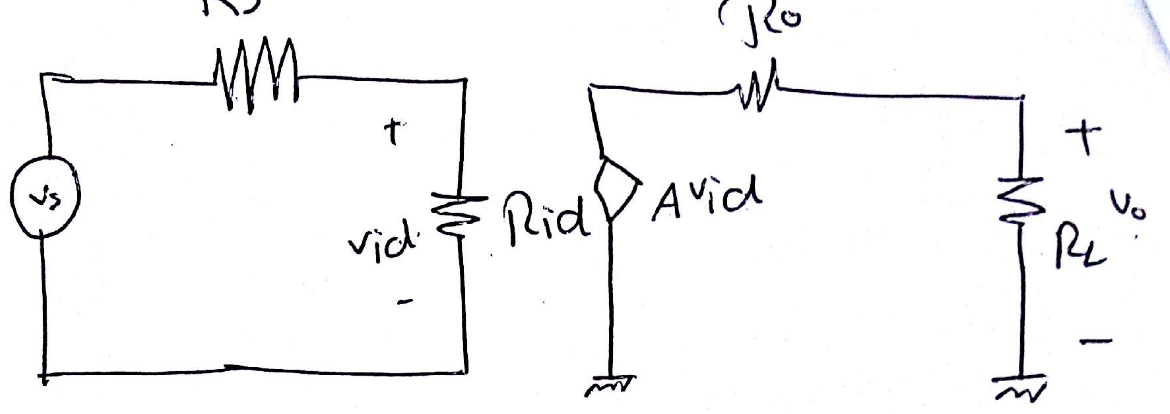
$A_{dB} = 20\log A$

1) op-Amp



$R_s = 5\,k\Omega$, $R_L = 1\,k\Omega$, $R_{id} = 1\,M\Omega$, $R_o = 0.5\,\Omega$

$A_{dB} = 60\ dB$

$60\,dB = 20\log A$ $\qquad A = 10^3\ V/V$

find

a) $A_v = \dfrac{V_o}{V_s} = \dfrac{V_o}{V_{id}} * \dfrac{V_{id}}{V_s}$

$= \boxed{A \dfrac{R_L}{R_L + R_s} \cdot \dfrac{R_{id}}{R_{id} + R_s}}$

$= 10^3 \dfrac{1K}{1K + 0.5\Omega} \cdot \dfrac{1M\Omega}{1M\Omega + 5k\Omega}$

$\boxed{A_v = 990}$

b) $V_s = ??$ $\qquad V_o = 10\,V\ P.P$

$A_v = \dfrac{V_o}{V_s}$ $\qquad V_{s\,P\text{-}P} = \dfrac{10}{990} = 0.01\,V$

2- $V_o = 10V$ $\quad A = 100\,dB = 10^5$

$100 = 20 \log A$

$A = 10^5$

a) $Vid = ??$

بلشت كن وشان 10^5 رح تصير

b) A ?? $\quad vid \leq 1\mu V$

<u>Solution</u>

$$V_o = A\,[v^+ - v^-]$$

$$\boxed{V_o = A\, Vid}$$

$$10 = 10^5\, vid$$

$$\boxed{vid = \frac{10}{10^5}}\ V$$

ثابت

b) $\boxed{A = \frac{V_o}{vid}} = \frac{10}{1\mu V}$

عكسي

$\leq 1\mu V$

$A \geq 10^7$

$$A = 10 \times 10^6$$

$$\boxed{A = 10^7}$$

$Av = ??$

$i_1 = I_2$

$$\frac{V_i - V_-}{R_1} = \frac{V_- - V_o}{R_2}$$

$V_- = V_+$

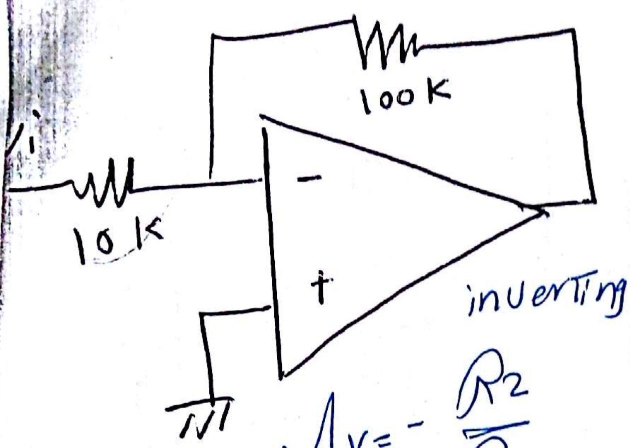
$I_+ = 0$

$$A = -\frac{R_2}{R_1}$$

$R_{in} = R_1$

$R_o = 0$

3) Find A_v, R_{in}, R_{out}



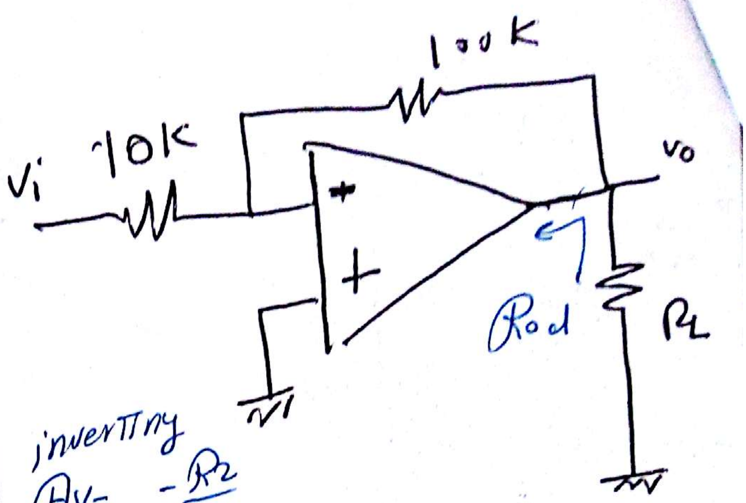
inverting

$A_v = -\frac{R_2}{R_1}$

$A_v = -10$ V/V

$R_i = 10\,k\Omega$ R_1

$R_{out} = 0$



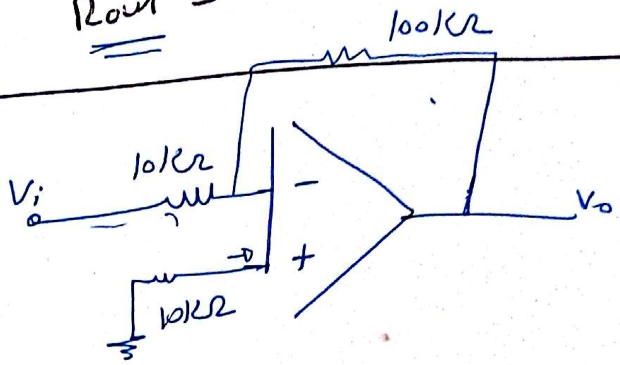
inverting

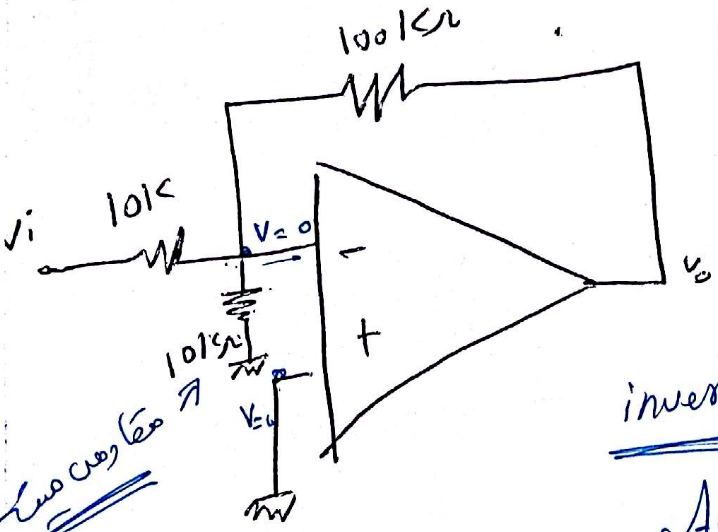
$A_v = -\frac{R_2}{R_1}$

$A_v = -10$ V/V

$R_{in} = 10\,k\Omega$ R_1

$R_{out} = 0\,\Omega$





inverting

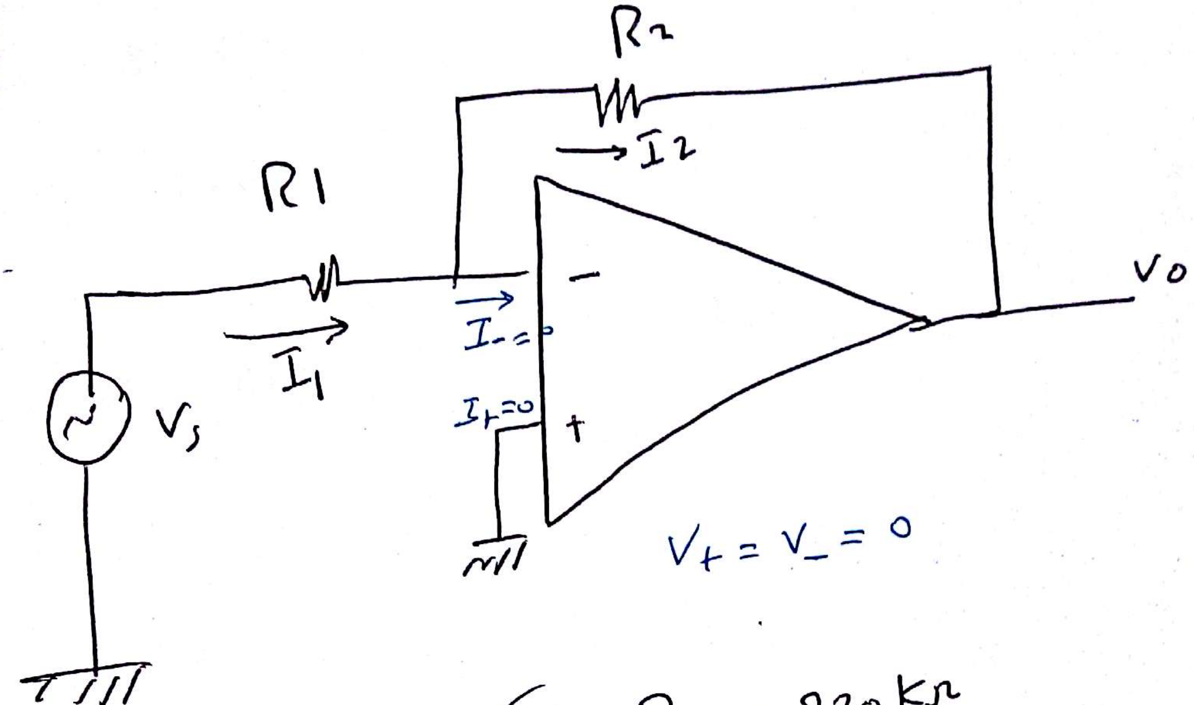
$A_v = -\frac{R_2}{R_1} = \frac{100k}{10k} = -10$

$A_v = -10$ V/V

$R_{in} = 10\,k\Omega = R_1$

$R_{out} = 0 \quad = 0$

9) Find expression for gain



$V_+ = V_- = 0$

$R_1 = 4.7\,K\Omega$ & $R_2 = 220\,K\Omega$

solution

$R_{in} = R_1 = 4.7\,K\Omega$ #

$R_{out} = 0$ #

$$I_1 = I_2$$

$$\frac{V_s - \overset{=0}{\cancel{V_-}}}{R_1} = \frac{\overset{0}{\cancel{V_-}} - V_o}{R_2}$$

$$\boxed{V_o = -\frac{R_2}{R_1} V_1}$$ #

$$A = \frac{V_o}{V_i} = -\frac{R_2}{R_1} = -\frac{220}{4.7K} = -46.81$$ #

20 log 46.81

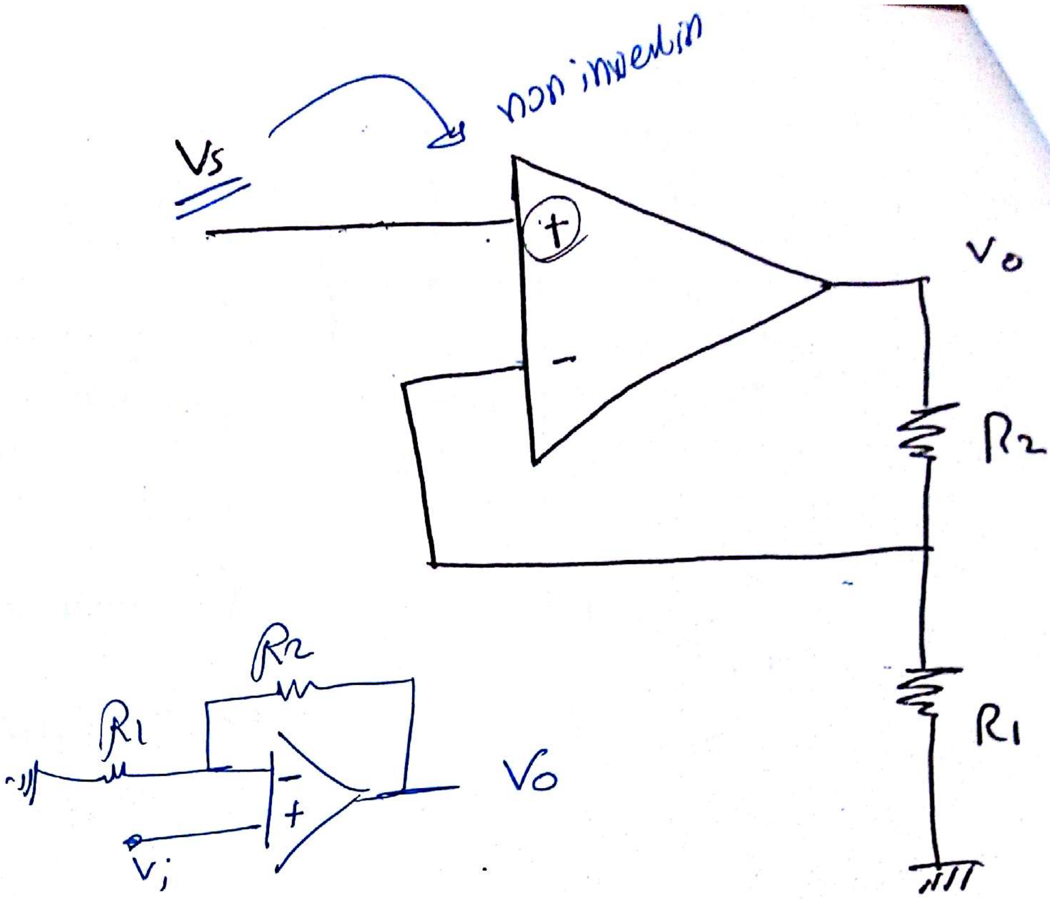
$A_{v_{dB}} = 20 \log 46.81 = 33.41\,dB$ #

(5)

$R_1 = 8.2\,k\Omega$

$R_2 = 680\,k\Omega$

$A_v,\ R_i,\ R_o$



solution

$$\boxed{A_v = 1 + \frac{R_2}{R_1}} = 1 + \frac{680K}{8.2K}$$

$$R_i = \infty = \frac{V_s}{I_i} \quad I_i = i^+ = 0$$

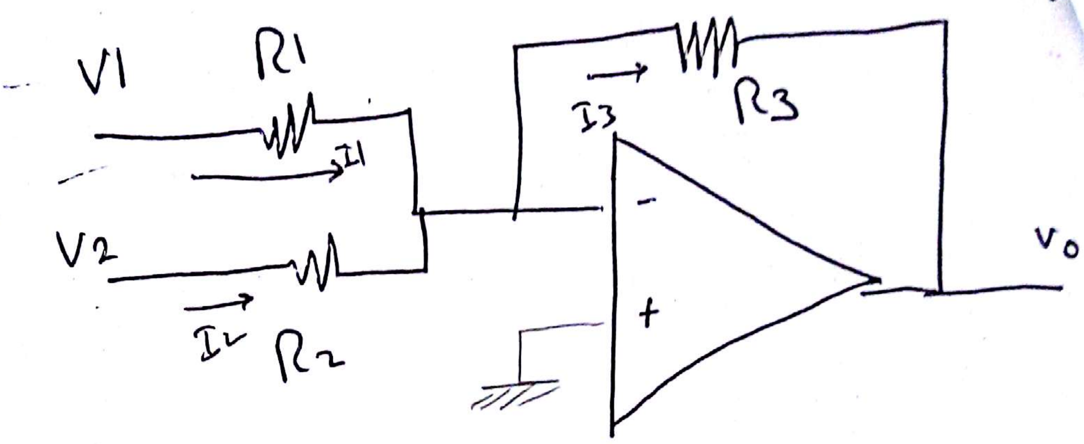
$\frac{V_s}{I_s} \rightarrow I_s = I_+$

$I_+ = 0$

$$R_{out} = 0$$

$\frac{V_s}{0} = \infty$

(6)



$V_2 = 0.04 \sin(10000t)$

$V_1 = 0.01 \sin 3770t$

$R_1 = 1k\Omega$

$R_2 = 2k\Omega$

$R_3 = 51k\Omega$

Solution

$V_- = V_+ = 0$

$$\boxed{I_1 + I_2 = I_3}$$

$$\frac{V_1 - 0}{R_1} + \frac{V_2 - 0}{R_2} = \frac{0 - V_0}{R_3}$$

$$V_0 = -\left[\frac{R_3}{R_1} V_1 + \frac{R_3}{R_2} V_2\right]$$

summing function

$$V_0 = -\left[51k * 0.01 \sin(3770t) + \frac{51k}{2} * 0.04 \sin(1000\ldots\right.$$

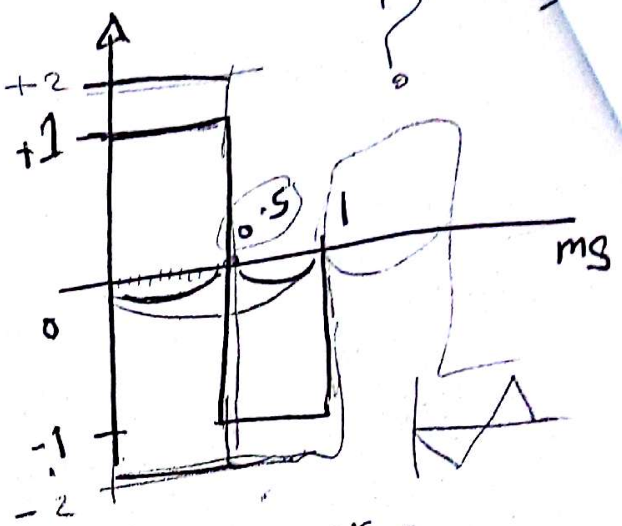
Sin — + — Sin

=

(7)

(8)

Miller integerator



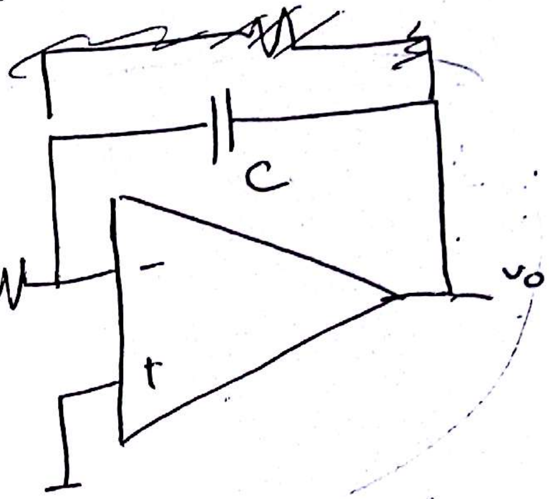
Sketch v_o

a) $\tau = 1ms = R.C$

time constant

b) ± 2

c) $\tau = 2ms$



$V_C = (0)$

Solution

$$V_o = \boxed{-\frac{1}{\underset{2ms}{R.C}} \int V_i \, dt} + V_c(0)$$

$$V_i = 1V = 2V$$

$0 \longrightarrow 0.5\ ms$

$$V_o = -\frac{1}{\underset{2ms}{1ms}} \int_0^{t\ (.5)} 1 \, dt + 0$$

$$[t]_0^t \quad 0.5$$

$$= -10^3$$

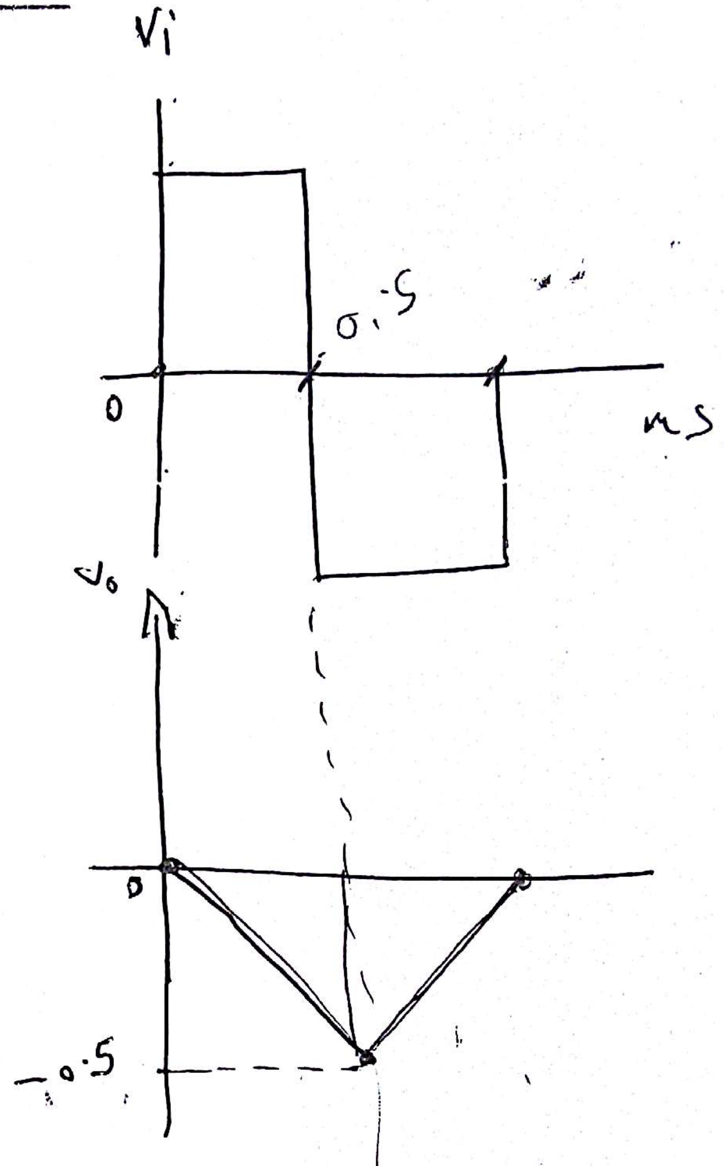
0.5

$$V_0 = -10^3 \, [t]$$

$$= -10^3 \cdot t$$

$0 < t < 0.5$

$$V_0(0.5\,ms) = -0.5\,V$$



$0.5\,ms \longrightarrow 1\,ms$

$V_c = V_0(0.5) = -0.5\,V$

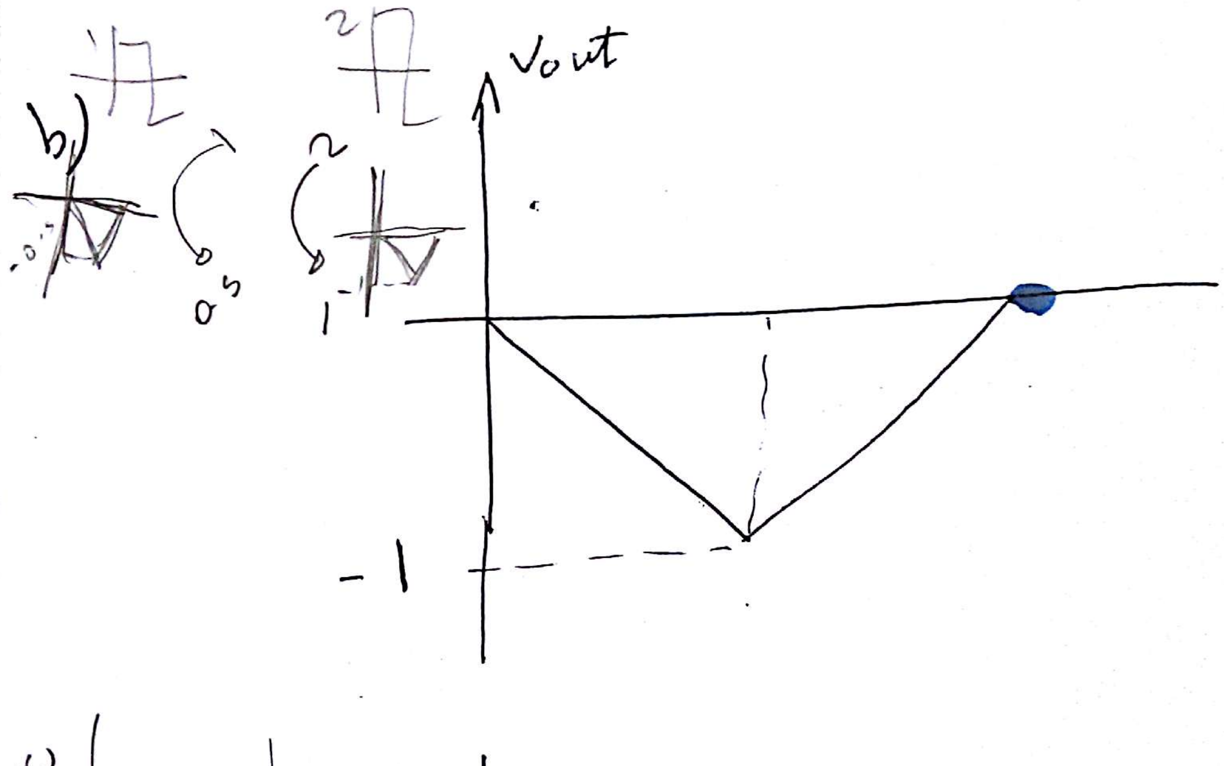
$$V_0 = -\frac{1}{RC} \int_{0.5}^{t} v_i \, dt - 0.5\,V$$

$$v_0 = -10^3 \int_{0.5}^{t} -1 \, dt - 0.5$$

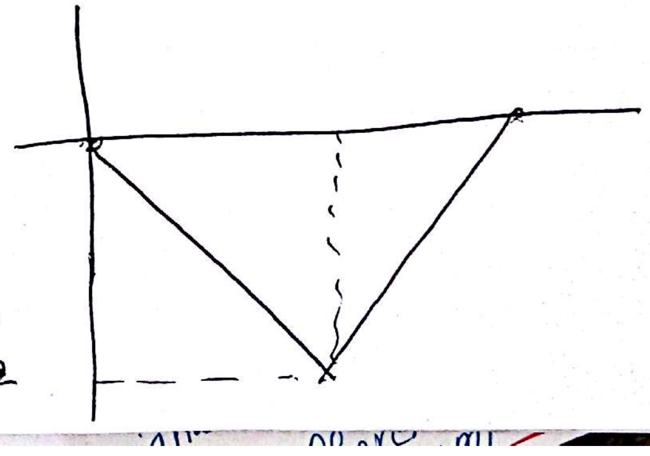
$$= 10^3 \left[t \right]_{0.5ms}^{t} - 0.5$$

$$\boxed{v_0 = (t - 0.5) - 0.5}$$

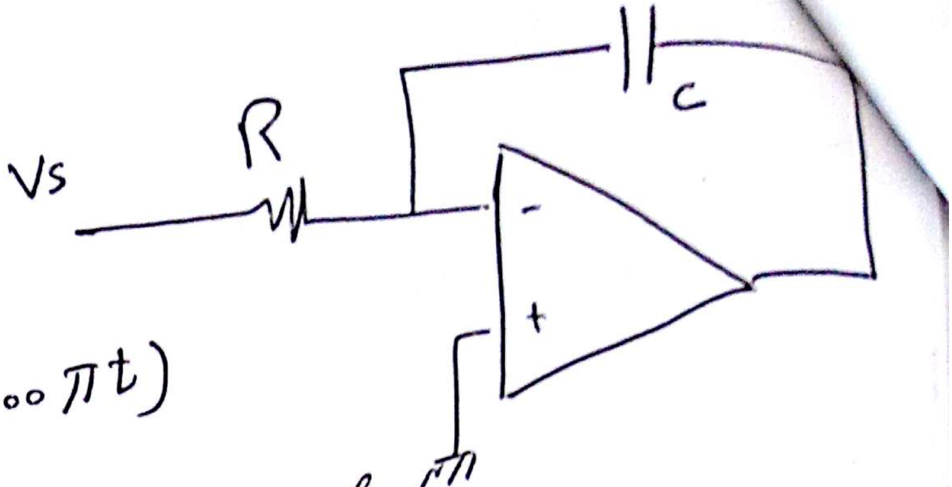
b)



c) $v_0 = -\frac{1}{RC}$



(9)



$V_s = 0.1 \sin(2000\pi t)$

$R = 10\,k\Omega$ & $C = 0.005\,\mu f$

$V_o(0) = 0$ find v_o

⇒ Solution $\tau = R.C$

$$v_o = \frac{-1}{RC} \int v_i \, dt + v_c(0)$$

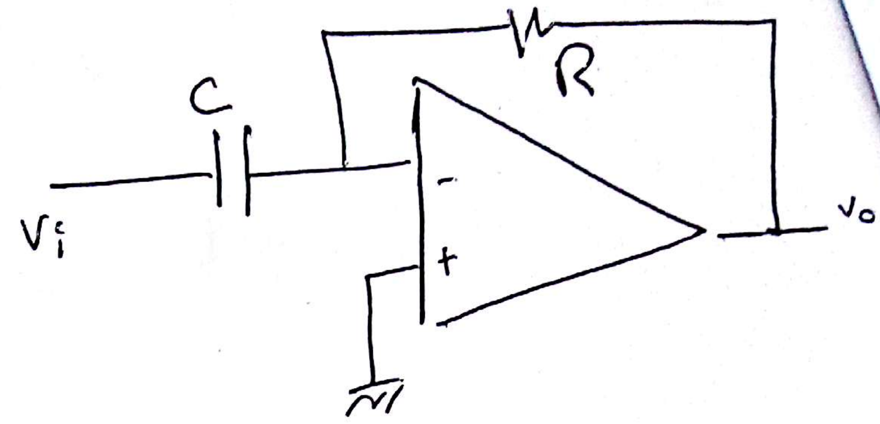
$$= \frac{-1}{RC} \int_0^T 0.1 \sin 2000\pi t \, dt$$

$$= \frac{0.1}{RC} \frac{\cos 2000\pi t}{2000\pi}$$

10×10^3 0.005×10^{-6}

(1)

(10):



$R = 10\,k\Omega$

$C = 0.01\,\mu f$

find

1) $f \Rightarrow$ at $V_i = V_o$

$|V_i| = |V_o| \Rightarrow A_v = \left|\frac{V_o}{V_i}\right| = 1$

solution

$$V_o = -RC\,\frac{dV_i}{dt} \qquad \frac{d}{dt} = s = jw$$

$$V_o = -Rc\,s\,V_i$$

$$\frac{V_o}{V_i} = -jw\,R.C$$

$$\left|\frac{V_o}{V_i}\right| = w\,R.C$$

$$\left|\frac{V_o}{V_i}\right| = 2\pi f.R.c$$

$$1 = 2\pi f.RC$$

$$\therefore f = \frac{1}{2\pi R.C} = 1.59\,kHz$$

S-11Sh

b). $\because V_{i_{p-p}} = 1V$

$V_0 \Rightarrow f_{new} = 10 f_0$

$10 f_0$

$f_{new} = 15.9\ kHz$

$$\boxed{\left|\frac{V_o}{V_i}\right| = 2\pi f \cdot R \cdot C}$$

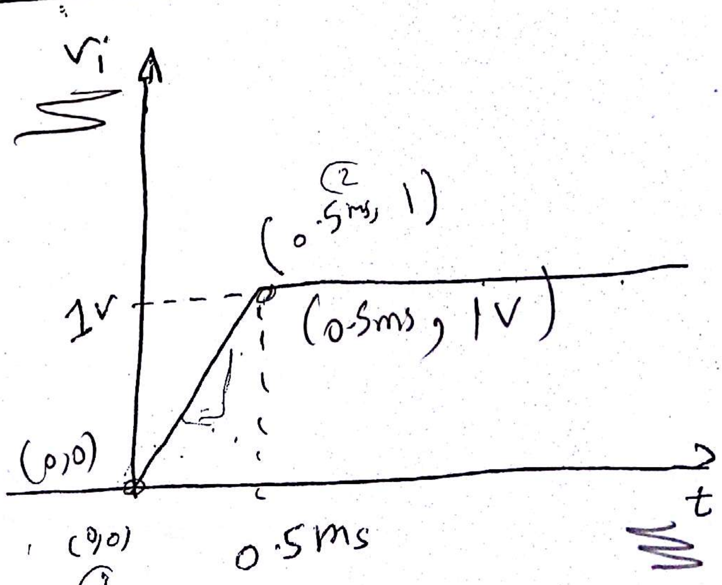
$$\frac{V_o}{1V} = 2\pi \cdot 15.9\ kHz \cdot R \cdot C$$

$$V_o = 1V\ [2\pi * 15.9 * 10^3\ R \cdot C]$$

---

(11) o P-AMP differential

$\tau = 1ms$



(1

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$$\frac{y_2 - y_1}{x_2 - x_1} = \frac{y - y_1}{x - x_1}$$

$$\frac{1 - 0}{0.5\ ms} = \frac{V_i - 0}{t - 0}$$

$\int$ square $\rightarrow$ line

$\frac{d}{dt}$ line $\rightarrow$ square

$\frac{d}{dt}$ square $= 0$

$$V_i = \frac{1}{0.5ms}\ t$$

$$\frac{dv_i}{dt} = \frac{1}{0.5\ ms} = 2 * 10^3$$

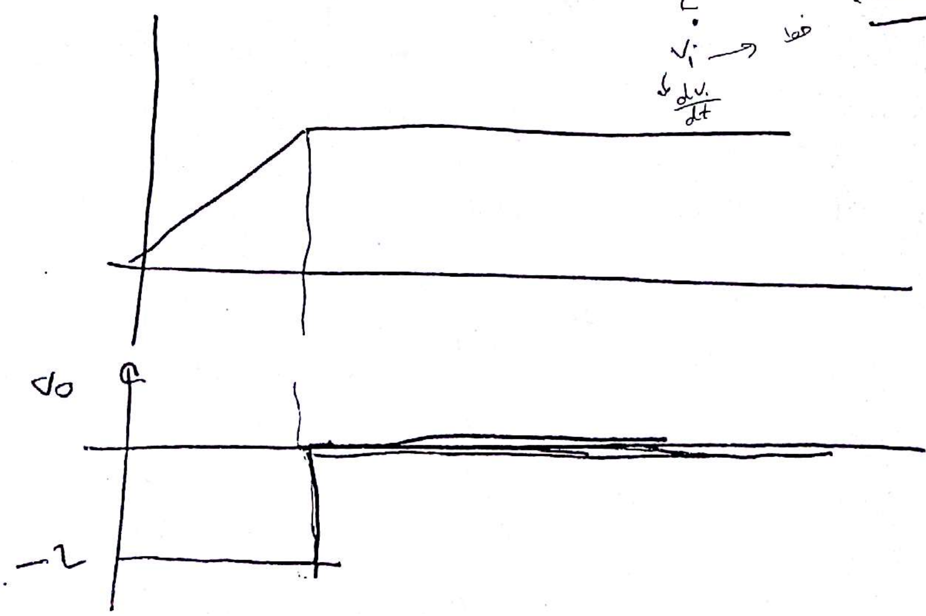
$$\boxed{V_o = -R \cdot C * \frac{dv_i}{dt}} = -1 * 10^{-3} * 2 * 10^3$$

?

$V_i \rightarrow$ خط

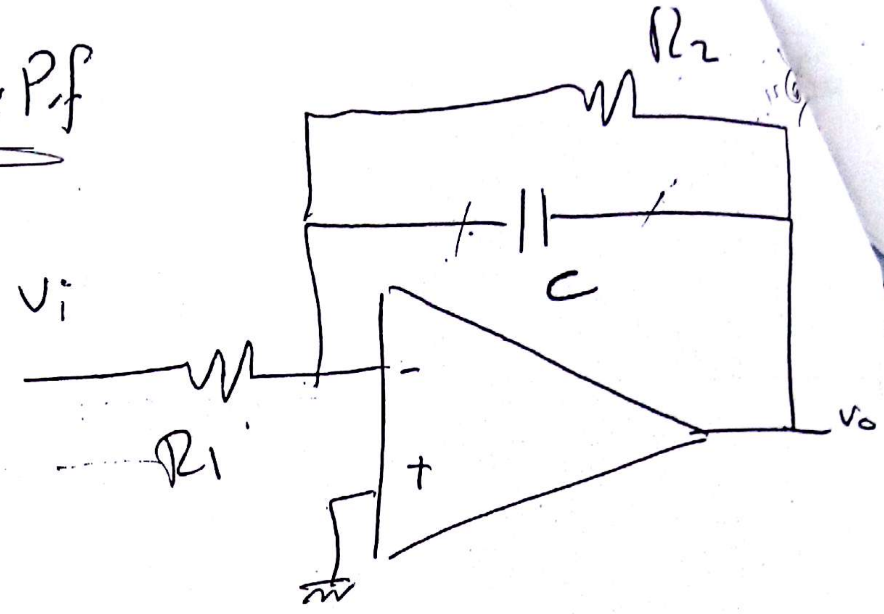
$\downarrow \frac{dv_i}{dt}$

$$= \underline{\underline{-2\ V}}$$



Q11 // Design L.P.f

C, L ̸ ꓡ



$R_i = 10\,K\Omega$

mid-range = 20 dB = 10 ↳ $20\log A_v$ $A_v = 10$

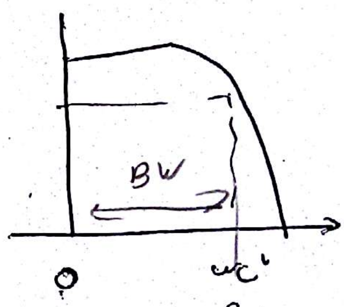
B.w = 20 KHZ

find R_1, R_2, C

solution

BW=20KHz = $f_L = 20k$

$R_{in} = R_1 = 10\,K\Omega$



BW = f_L

$$\text{dc gain} = -\frac{R_2}{R_1}$$

$$|\text{dc gain}| = \frac{R_2}{R_1}$$

$$10 = \frac{R_2}{10\,K\Omega}$$

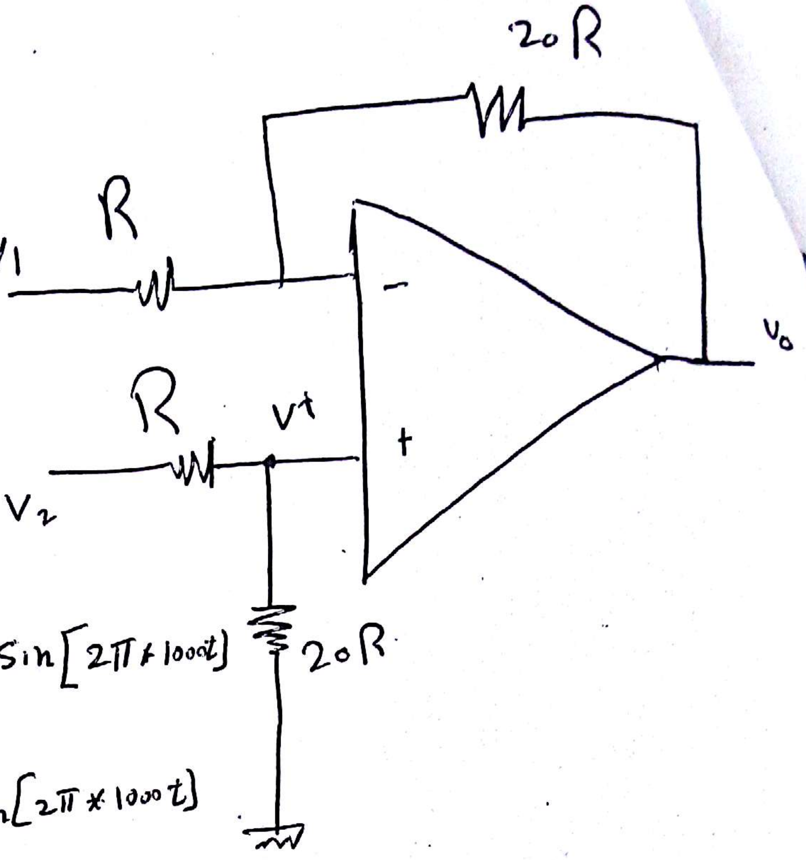
$$\boxed{R_2 = 100\,K\Omega}$$

$$\underset{20K}{f_c} = \frac{1}{2\pi R_2 C}$$

(13)

find V_o

using super position



$V_1 = 10\sin[2\pi * 60t] - 0.1\sin[2\pi * 1000t]$

$V_2 = 10\sin(2\pi * 60t) + 0.1\sin[2\pi * 1000t]$

solution

$V_o = +\frac{R_2}{R_1}(V_2 - V_1)$

$V_o = 20\,[10\sin 2\pi 60t + 0.1\sin 2\pi 1000t - 10\sin 2\pi 60t + 0.1\sin 2\pi 1000t]$

due to V_1

$V_o = -\frac{R_f}{R_{in}} V_1$

$V_o = -\frac{20\cancel{R}}{\cancel{R}} V_1 = \boxed{-20\, V_1}$

$V_o = 20 \times 0.2 \sin 2\pi 1000t = 4 \sin 2\pi 1000t$

due to V_2

$V_o = (1 + \frac{R_f}{R}) V_+$

$V_o = (1 + \frac{20R}{R}) V_+$

$= \cancel{21} * \frac{20\cancel{R}}{\cancel{21}\cancel{R}} V_2$

$V_o = 20 \cdot V_2$

$$\therefore V_o = 20 V_2 - 20 V_1$$

$$v_o = 20 [V_2 - V_1]$$

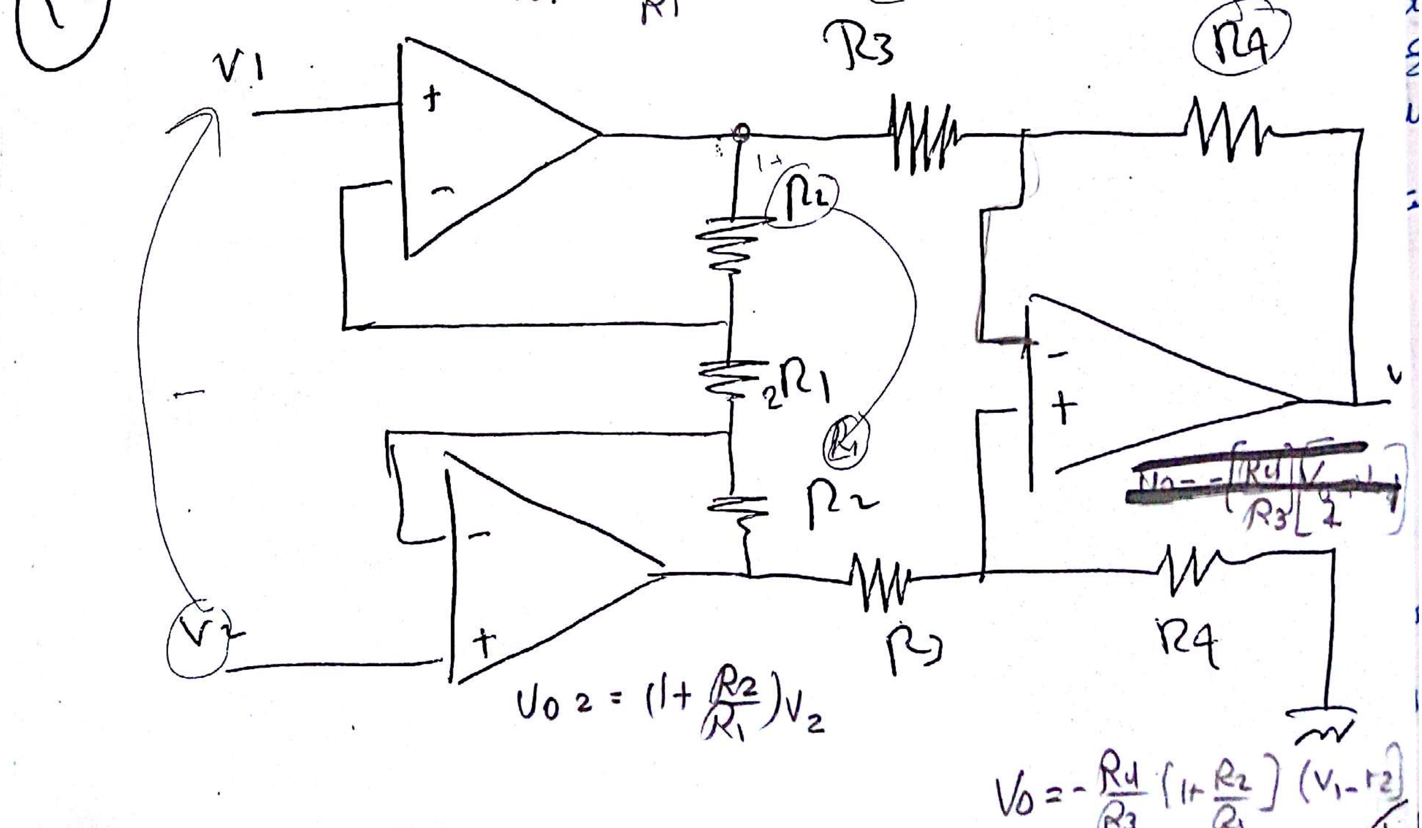
$$V_o = 20 [0.2 \sin(2\pi * 1000t)]$$

$$\boxed{V_o = 4 \sin(2\pi * 1000t)}$$

---

(14)

$$V_{o1} = \left(1 + \frac{R_2}{R_1}\right) V_1$$

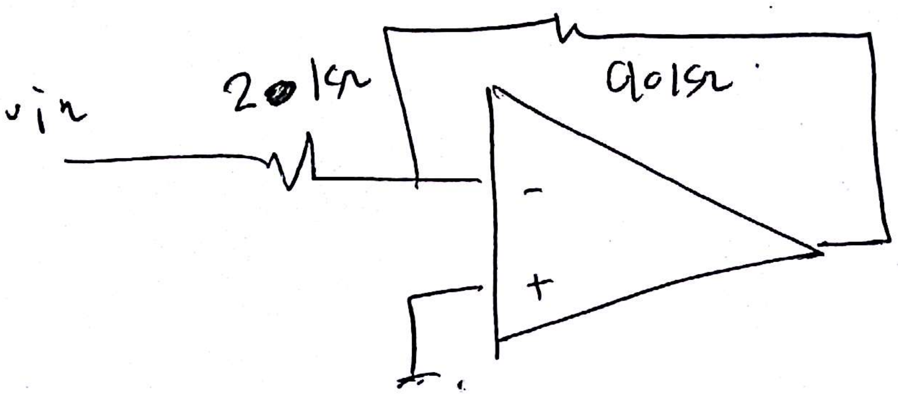


$$V_{o2} = \left(1 + \frac{R_2}{R_1}\right) V_2$$

$$V_o = -\frac{R_4}{R_3}\left[1 + \frac{R_2}{R_1}\right](V_1 - V_2)$$

$$V_0 = -\frac{R_4}{R_3}\left[1+\frac{R_2}{R_1}\right]\left[V_1 - V_2\right]$$

Cascade



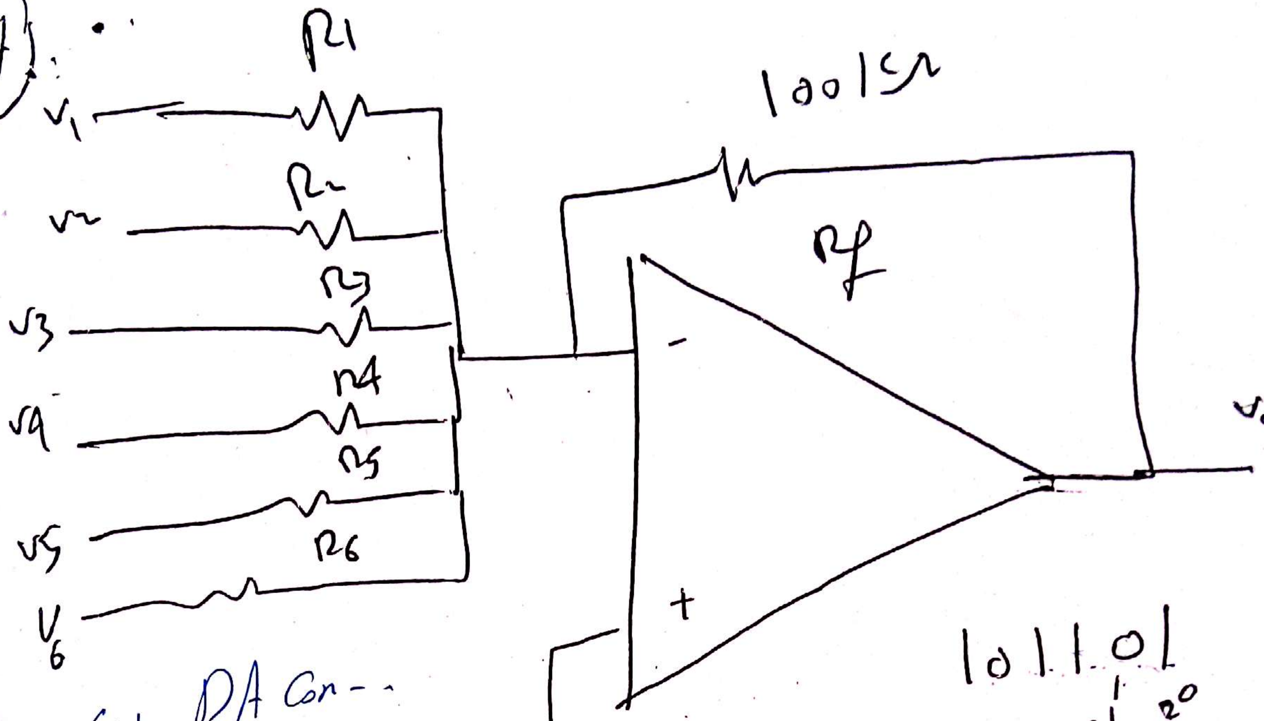
$R_{in} = 20k\Omega$

$A_v = -20$

$R_{out} = 0$

S-1Pr ms4r(

(7)



1011.01

2^1 2^0

6bit DA Con--

D → A Converter

binary

AD

$$V_0 = -\left[\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3 + \frac{R_f}{R_4}V_4 + \frac{R_f}{R_5}V_5 + \frac{R_f}{R_6}V_6\right]$$

2^0 1, ×2, 2 2^1, ×2, 4 2^2, ×2, 8 2^3, ×2, 16 2^4, ×2, 32 2^5

$$2^0 = 1 = \frac{R_f}{R_1}$$

$$R_f = R_1 =$$

$$2 = \frac{R_f}{R_2}$$

$$R_2 = \frac{R_f}{2}$$

$$R_3 = \frac{R_f}{4}$$

$$R_5 = \frac{R_f}{16},\quad R_6 = \frac{R_f}{32},\quad R_4 = \frac{R_f}{8}$$

non-ideal op-amp

[a] Non inverting op-amp
- Gain
- Rin
- Rout

[b] inverting op-amp
- Gain
- Rin
- Rout

* Frequency Responce of op-amp
- " " " inverting
- " " " non inverting
- " " " cascaded amplifier

غالباً مش خلاص

* Finite Common mode Rejection Ratio
* voltage follower Gain error due To CMRR
* offest voltage
* offest voltage adjustment
* slow Rate (SR)

Scanned by CamScanner

non ideal op-amp

وهو النوع التاني من ال operational amplifier ففي النوع الأول قمنا بتحليل مجموعة من الدواير الخاصة ب ideal op - amp وكانت خواصها :

[1] open loop Gain $A = \infty$

[2] $R_i = \infty$

[3] $R_{out} = 0$

كل هذه الشروط تخص ال ideal-op-amp ولكن في هذا الجزء سوف نقوم بتحليل دايرة ال op-amp من خلال non-ideal فنجد أن

- open loop Gain $\neq \infty$
  - But Finite open loop Gain $A \neq \infty$
- output resistance $\neq 0$
  - But Non-zero output. Resistance $R_{out} \neq 0$
- input Resistance $\neq \infty$
  - But Finite input Resistance.

وهو ده الي هندرسه ← هندرس أن ① $A \neq \infty$

خواص ال non-ideal op-amp
② $R_{out} \neq 0$
③ $R_{in} \neq \infty$

#

[a] Non-inverting op-amp → (input signal $\xrightarrow{on}$ +ve port)

هنا خد النوع ده مثال وتطلع ① A_v ← اعتبر $R_o = 0$ $R_i = \infty$

② R_{in} ← اعتبر $R_{out} = 0$

③ R_{out} ← اعتبر $R_{in} = \infty$

ابتداء من ما جيه

(1) finite open-Loop Gain $A \neq \infty$

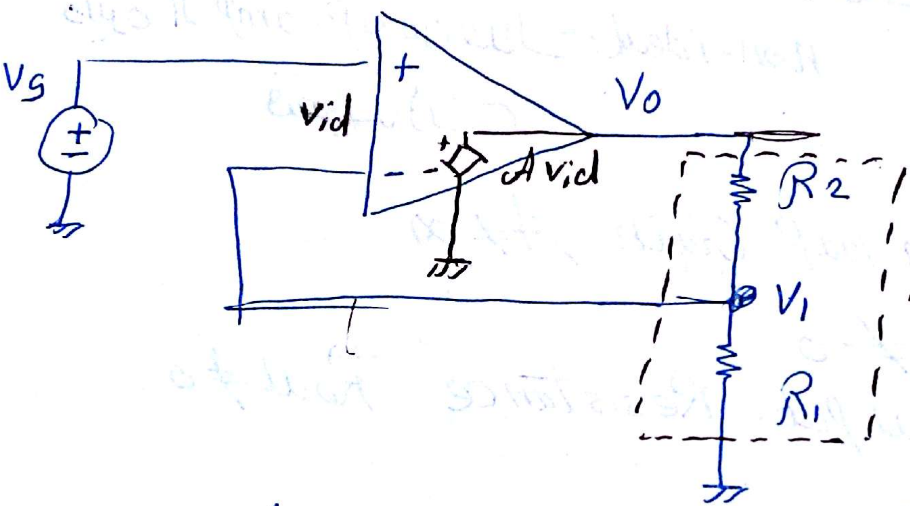
- في هذا الجزء سوف نقوم بمعرفة تأثير الـ A عند مايكون قيمته لا تساوي (∞) و أن لها قيمة محدوده
- سوف نقوم بحساب A_v للدايره التاليه ولكن $A \neq \infty$ كما علمنا في ideal

Reminder That

A: open loop Gain → دي في الداتا شيت

A_v: Closed loop Gain → بعد توصيل الـ feedback

Non inverting i/p → +



المقاومات R_2 & R_1 مسؤولين عن الـ feedback لذلك يسموا feed back Pair

$V_o = A\, V_{id}$ (1) A: open loop Gain

$V_{id} = V_s - V_1$ (2)

$i_- = 0$

$$V_1 = V_o \times \underbrace{\frac{R_1}{R_1 + R_2}}_{\beta}$$

feedback factor $= \beta = \dfrac{R_1}{R_1 + R_2}$

$V_1 = V_o\, \beta$ (3)

from (1), (2), (3)

$V_o = A\,[V_s - V_1]$

$V_o = A\,[V_s - \beta V_o]$

$V_o = A V_s - A\beta V_o$

$V_o\,[1 + A\beta] = A V_s$

$$\boxed{A_v = \frac{V_o}{V_s} = \frac{A}{1 + A\beta}} \#$$

$A\beta$: Called Loop Gain

→ approximation

قريب باستخدام الشرط ده ؟

$A\beta >>> 1$

شرط من شروط الـ feedback في الـ ideal op-amp

$$A_v = \frac{A}{A\beta} = \frac{1}{\beta} = \frac{1}{\frac{R_1}{R_1 + R_2}}$$

$$A_v = 1 + \frac{R_2}{R_1}$$

هي الـ ideal

$$\therefore A_{ideal} = \frac{1}{\beta} = 1 + \frac{R_2}{R_1}$$

$$A = \frac{V_o}{V_S} = \frac{A}{1+A\beta}$$

and

$$V_{id} = V_S - V_1 = V_S - \beta V_o = V_S - \beta \left(\frac{A}{1+A\beta} V_S \right)$$

V_o

$$V_{id} = V_S \left[1 - \frac{A\beta}{1+A\beta} \right]$$

$$V_{id} = V_S \left[\frac{A\beta + 1 - A\beta}{1+A\beta} \right] = V_S \left[\frac{1}{1+A\beta} \right]$$

$$\boxed{V_{id} = \frac{V_S}{1+A\beta}}$$

$$V_o = A\, V_{id} = \frac{A}{1+A\beta} V_S$$

هيظهر عندي تعريفين مهمين جداً

→ Gain Error "GE": is defined as the difference between the ideal Gain and the acual Gain

GE = ideal Gain - actual Gain

→ Fractional Gain Error (FGE)

هو نسبة ال GE من ال ideal Gain

$$FGE = \frac{\text{ideal Gain} - \text{actual Gain}}{\text{ideal Gain}}$$

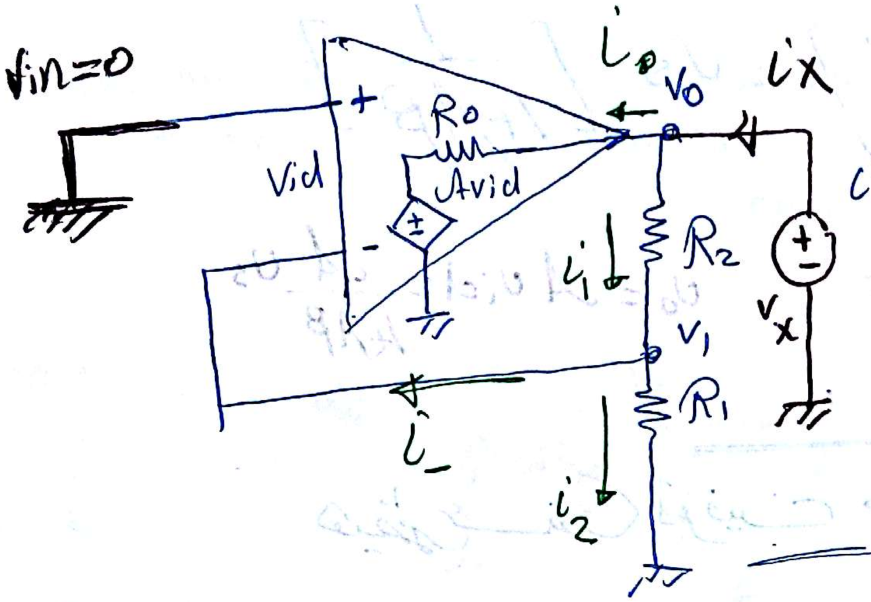
$$\frac{1}{\beta} = \left(1 + \frac{R_2}{R_1}\right)$$

- $GE = \frac{1}{\beta} - \frac{A}{1+A\beta} = \frac{1}{\beta(1+A\beta)}$
- $FGE = \frac{\frac{1}{\beta(1+A\beta)}}{\frac{1}{\beta}} = \frac{1}{(1+A\beta)} \simeq \frac{1}{A\beta}$

$A\beta \gg 1$.

non-Zero output Resistance

في هذا الجزء عندما كنا نضع الـ $R_{out}=0$ لدوائر ideal-op amp analysis
ولكن في هذا الجزء سوف نقوم بالتعرف على كيفية إيجاد قيمة Rout
في حالة الـ non-ideal op-amp ≡ Practical op-amp



• Reminder That

لإيجاد Rout
إيجاد source اسمه V_x بيطلع تيار i_x
ونضعه عند output port

$\therefore R_{out} = \dfrac{V_x}{i_x}$

ولا تنسى تضع $\underline{V_{in} = 0}$

$$R_{out} = \frac{V_x}{i_x}$$

لابد إيجاد علاقة بين i_x & V_x

$i_x = i_o + i_2$ at o/p port

$$i_o = \frac{V_x - A V_{id}}{R_o} \#$$

~~$i_2 = V_x$~~

$$\boxed{V_x = i_1 R_1 + i_2 R_2}$$

$i_1 \simeq i_2 \qquad i_- = 0$

$$V_x = i_2 (R_1 + R_2)$$

$$\therefore i_2 = \cancel{i_1} = \frac{V_x - \cancel{V_1}}{R_1 + R_2} \#$$

$$V_x = i_1 R_1 + \frac{V_x}{R_1 + R_2}$$

بدلالة V_x

$$V_{id} = V_+ - V_- = 0 - V_1$$

$$= -V_1 = -V_x \times \boxed{\frac{R_1}{R_1+R_2}} \; \beta$$

$$V_{id} = -\beta V_x$$

$$\therefore i_x = i_o + i_2$$

$$i_x = \frac{V_x - A V_{id}}{R_o} + \frac{V_x}{R_1 + R_2}$$

$$i_x = \frac{V_x}{R_o} - \frac{A V_{id}}{R_o} + \frac{V_x}{R_1 + R_2}$$

بدلالة V_x — لابد بدلالة V_x أو i_x — بدلالة V_x

$$V_{id} = -\beta V_x$$

$$\therefore i_x = \frac{V_x}{R_o} + \frac{A\beta}{R_o} V_x + \frac{V_x}{R_1+R_2}$$

$$i_x = V_x \left[\frac{1+A\beta}{R_o}\right] + \frac{V_x}{R_1+R_2} = V_x \left[\frac{1}{\frac{R_o}{1+A\beta}} + \frac{1}{R_1+R_2}\right]$$

$$\frac{V_x}{i_x} = \frac{1}{\frac{1}{\frac{R_o}{1+A\beta}} + \frac{1}{R_1+R_2}}$$

$R_1 // R_2$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{out} = \frac{R_o}{1+A\beta} // R_1+R_2 \quad \#$$

$$\boxed{R_{out} \approx \frac{R_o}{1+A\beta}} \quad \#$$

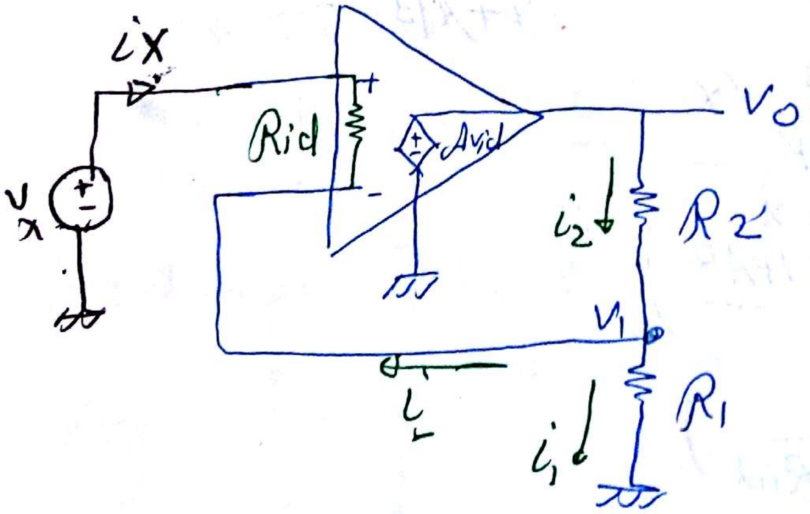
R_{out} closed loop Gain O/P Resistance ← بعد التوصيل

R_o open " " " " ← من data sheet

3 Finite input Resistance

في هذا الجزء سوف نحاول إيجاد Rin لل non ideal op-amp

$R_{in} \neq \infty$



Reminder That

لإيجاد Rin بنحط عنال source للـ i/p Port اسمه Vx وبيطلع current اسمه ix

$$\therefore R_{in} = \frac{V_x}{i_x}$$

$R_{in} = \frac{V_x}{i_x}$

$i_x = \frac{V_x - V_1}{R_{id}} = \frac{V_x}{R_{id}} - \frac{V_1}{R_{id}}$

and

$V_1 = i_1 R_1$

V_x بدلالة

لابد اجاوه بدلالة V_x و i_x

$i_1 = i_2 - i_-$

$i_- = 0$

$i_1 \simeq i_2$

$\therefore V_1 = i_2 R_1$

$V_1 \simeq V_0 \frac{R_1}{R_1 + R_2} = \beta V_0$

$V_0 = A V_{id} = A(V_x - V_1)$

$V_0 = A V_x - A V_1$

$\cancel{V_0 =}$

$\therefore V_1 \simeq \beta(AV_x - \beta A V_1)$

$(1 + A\beta) V_1 = A\beta V_x \Rightarrow V_1 = \frac{A\beta V_x}{1 + A\beta}$

$\therefore i_x = \frac{V_x}{R_{id}} - \frac{\frac{A\beta}{1+A\beta} V_x}{R_{id}}$

$i_x = V_x \left(\frac{1 - A\beta / 1 + A\beta}{R_{id}} \right)$

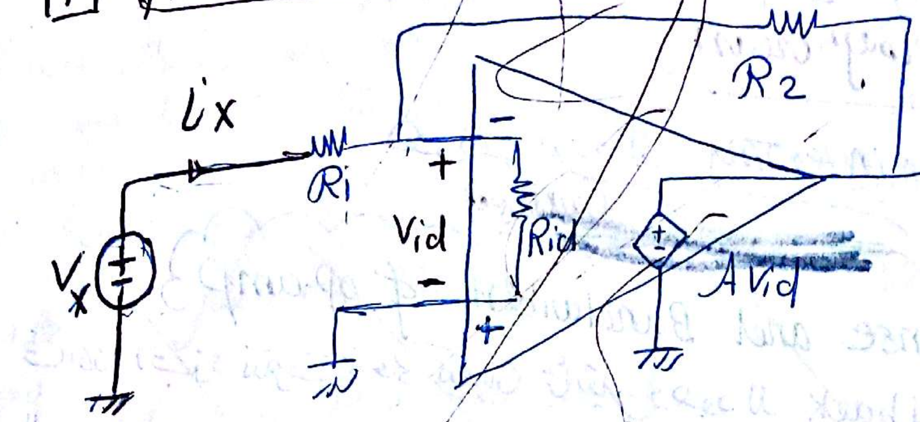
$i_x = V_x \left(\frac{1}{(1 + A\beta) R_{id}} \right)$

$R_{in} = \frac{V_x}{i_x} = (1 + A\beta) R_{id} \neq \infty$

[b] inverting op-amp → (input signal on → -ve port.)

Gain, R_o, R_{in} بالتالي هانجيب

[I] Finite input Resistance.



لإيجاد R_{in} نفرض V_x نطلع i_x عند i/p port
$\therefore R_{in} = \frac{V_x}{i_x}$

نحتاج لإيجاد معادلة تربط V_x & i_x

$$R_{in} = \frac{V_x}{i_x}$$

$$V_x = \underbrace{i_x}_{i_x \text{ بدلالة}} R_1 + \underbrace{V_{id}}_{\downarrow}$$

لابد من إيجاده بدلالة V_x أو i_x

$$V_{id} = V_- - V_+ = V_- - 0 = V_-$$

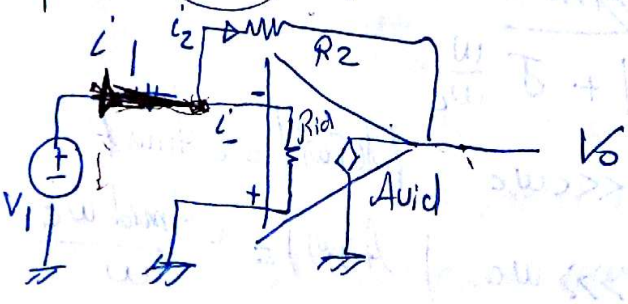
$$\therefore V_x = i_x R_1 + V_- \quad \div i_x$$

$$R_{in} = \frac{V_x}{i_x} = R_1 + \frac{V_-}{i_x} \quad \#$$

من القانون السابق يمكن تقسيم R_{in} إلى جزئين لتسهيل الحسابات وهو عبارة عن

$$R_1 + \frac{V_-}{i_x}$$

1 2



$$i_1 = i_- + i_2$$

$$= \frac{V_1 - 0}{R_{id}} + \frac{V_1 - V_o}{R_2} \qquad V_o = -AV_i$$

$$i_1 = V_1 \left[\frac{1}{R_{id}} + \frac{1+A}{R_2} \right]$$

$$\frac{V_1}{i_1} = \frac{1}{\frac{1}{R_{id}} + \frac{1}{\frac{R_2}{1+A}}}$$

$$\frac{V_1}{i_1} = R_{id} \parallel \frac{R_2}{1+A}$$

$$\therefore R_{in} = R_1 + R_{id} \parallel \frac{R_2}{1+A}$$

$$R_{in} \simeq R_1 + \frac{R_2}{1+A} \quad \#$$

(*) Finite Common mode Rejection Ratio

ماسبق وذكرنا في خصائص ال ideal op-amp

إن ال CMRR = 0 ولكن

ماهي ال CMRR ؟؟

كـ

if any Two i/p are the same are connected To the i/p of the op-amp

Then for ideal op-amp the o/p = 0

because the gain in this case will be zero

and the gain in this case called Common mode gain A_{cm}

Reminder That

- in ideal-op amp
  ↳ CMRR = 0
- Common mode

أن ال i/p بيدخل على ال 2 port الموجب والسالب

مع بعض

$V_o = A V_{id}$

$V_{id} = V_+ - V_-$

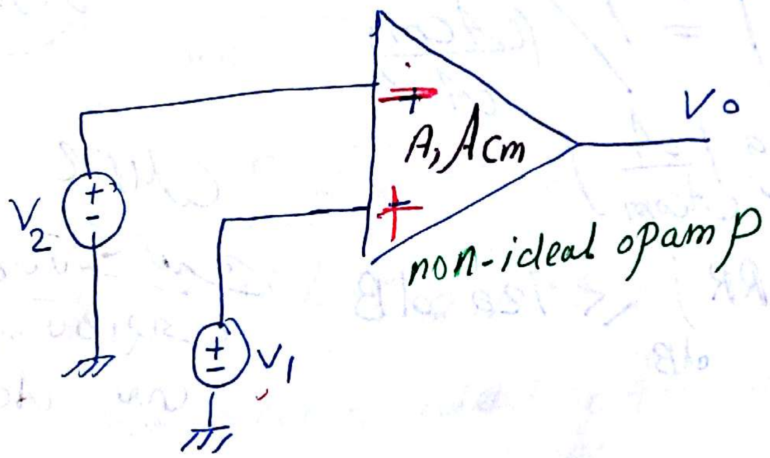
$\therefore V_{id} = 0 \rightarrow V_o = 0$

<u>But</u> in non ideal opamp

↳ when we Connect Two i/p voltage To the i/p the o/p of op-amp and common mode signal appear at Two i/p Terminal

يعني في حالة ال nonideal opamp

$A_{common} \neq 0$



$$V_{icm} = \frac{V_1 + V_2}{2}$$

Then

$$V_o = A\underbrace{(V_1 - V_2)}_{V_{id}} + A_{cm}\underbrace{\left(\frac{V_1+V_2}{2}\right)}_{V_{iCom}}$$

$$V_o = A V_{id} + A_{cm} V_{ic} \quad \# (1)$$

كان = 0 في ال ideal op-amp

$\therefore V_o = A V_{id} + 0$

A or Adm = differential mode Gain

Acm : Common mode Gain

Vidc: differential mode i/p

Vic : Common mode "

$V_{ic} = \frac{V_1 + V_2}{2}$

$V_{id} = V_1 - V_2$

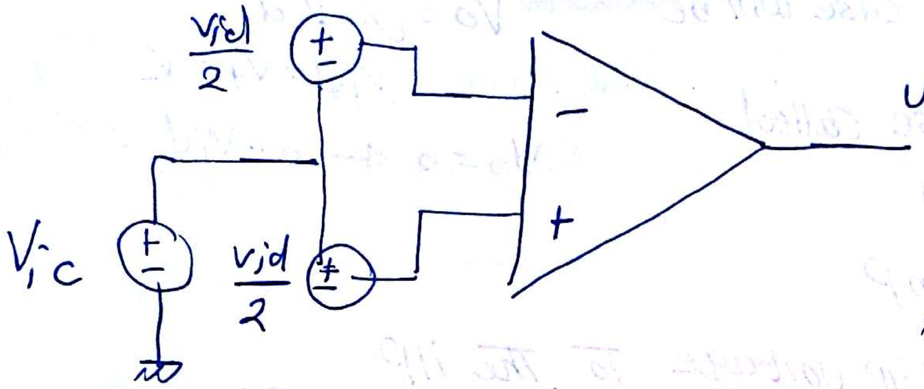
بالحل

$V_1 = V_{ic} + \frac{V_{id}}{2}$

$V_2 = V_{ic} - \frac{V_{id}}{2}$

The previous figure can be represent by

ممكن اعاده رسم الدايره السابقة باستبدال V_1 و V_2 بقيمهم الجديدة



الترم ده المفروض بيبقى صغير جدا

$V_o = A V_{id} + A_{cm} V_{ic}$

$V_o = A\left[V_{id} + \frac{A_{cm}}{A} V_{ic}\right] = A\left[V_{id} + \frac{V_{ic}}{CMRR}\right]$

$CMRR = \left|\frac{A}{A_{cm}}\right| = 1/\left(\frac{A_{cm}}{A}\right)$

$CMRR|_{dB} = 20 \log \left|\frac{A}{A_{com}}\right|$

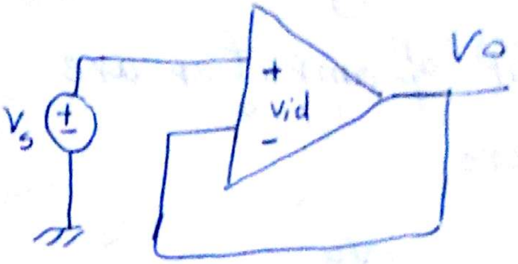
$60\,dB \leq |CMRR|_{dB} \leq 120\,dB$

CMRR
كل ما كانت كبيرة
كل ما كانت هتقلل
الـ Acm بتاعي

Voltage Follower Gain error due To CMRR

بنعرف انو ال A_v لل voltage follower بساوي 1 ولكن بنبين CMRR

if noninverting inverter



$$V_{id} = V_+ - V_- = V_S - V_o$$

$$V_{iC} = \frac{V_S + V_o}{2}$$

$$V_o = A\left[V_{id} + \frac{V_{iC}}{CMRR}\right] \#$$

$$V_o = A\left[(V_S - V_o) + \frac{V_S + V_o}{2\,CMRR}\right]$$

$$A_v = \frac{V_o}{V_S}$$

$$A_v = \frac{A\left[(V_S - V_o) + \frac{V_S + V_o}{2\,CMRR}\right]}{V_S}$$

$$A_v = \frac{A\left[1 + \frac{1}{2CMRR}\right]}{\left[1 + A\left[1 - \frac{1}{2CMRR}\right]\right]}$$

$$GE = \text{Gain error} = \text{ideal } A_v - \text{actual } A_v$$

$$= 1 - \frac{V_o}{V_S}$$

$$= 1 - \frac{A\left[1 + \frac{1}{2CMRR}\right]}{1 + A\left[1 - \frac{1}{2CMRR}\right]}$$

$$\boxed{GE \cong \frac{1}{A} - \frac{1}{CMRR}} \#$$

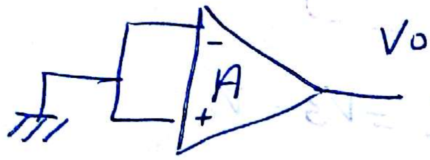
offest voltage.

عندما يكون الدخل للـ amplifier = 0

المفروض الخرج = 0

ولكن اللي بيحصل ←

when The i/p of amplifier are both zero



then The o/p should be zero, but The o/p will be rest at some dc voltage level

يعني $V_{id} = 0 \Longrightarrow V_o = dc$ value

وده تفسيره عامل واحده

يعني noise ← dc قيمتها صغيره دخلت على i/p واتكبرت طلعت dc value كبيره شويه

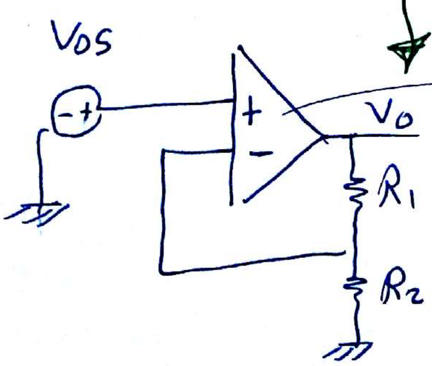
↳ A small dc voltage seems To have been applied To the i/p of The amplifier, which is amplified by Gain. ~~and~~

- equivalent dc i/p offest voltage

$$V_{os} = \frac{V_o}{A} \qquad V_{os} < 0.25\ mV$$

$$V_o = A\left[v_{id} + \frac{v_{ic}}{CMRR}\right] + V_{os}$$

علشان تفهمها على المثال ده



ideal op-amp with zero offest voltage

$$V_o = \left(1 + \frac{R_2}{R_1}\right) V_{os}$$

* offest voltage adjustment

(13)

دحل المشكلة دى إزاى ؟؟

لازم لما $0 = V_{in}$

$0 = V_o$

← فى الجزء السابق تعرفنا على مصدر من مصادر الـ error وهو

$V_{in} = 0 \longrightarrow V_o \neq$

نلاحظ لحل هذه المشكلة نلاحظ أن فى

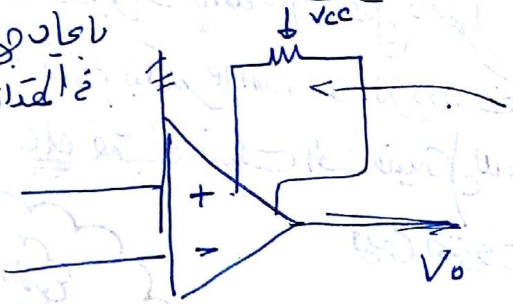
ap-amp له طرفان زيادة 1 و 5

نقوم بتوصيل مقاومة متغيرة بين هذين الطرفين .

والطرف الثالث للمقاومة المتغيرة يوصل على Vcc

وتغير فى المقاومة حتى يتلاشى Vos

باتجاه جهد مساوى فى المقدار ومضاد فى الاتجاه بـ Vos



PoTen Tiometer

نغير فيها لحد ما $0 = V_o$

لأن $0 = V_i$

1 و 5 أطراف فى الـ op-amp تسمى offest null

* slow rate SR

المقصود من الـ slow rate هو أن

إذا تم إدخال جهد معين على الـ op-amp فإنه يأخذ وقت معين حتى يتم الحصول عليه من على الخرج للـ op-amp وهذا الوقت يعرف بـ slow rate

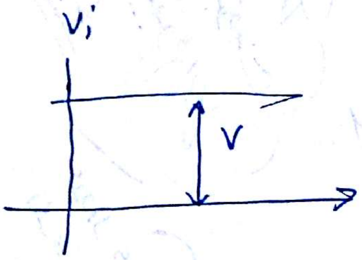
$$SR = \frac{dV_o}{dt}\Big|_{max}$$

ووحدته V/µs

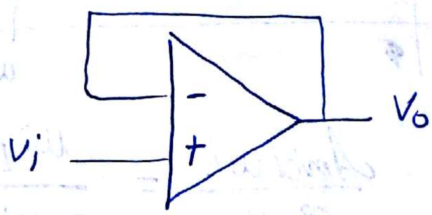
volt / µ second

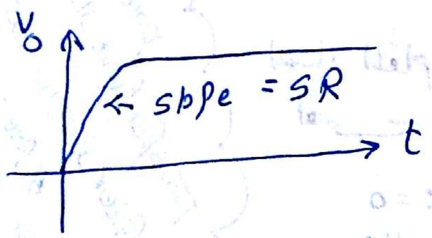
مثال على ذلك

voltage follower

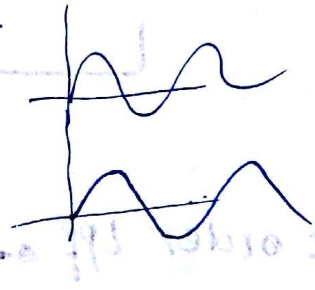


إذا تم توصيل هذه الإشارة على الـ

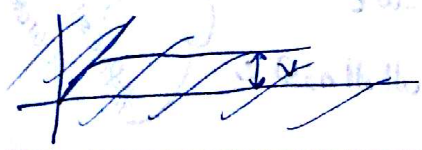




الخرج هيكون كده



التردد هيتغير فى الـ o/p



(*) Frequency response and Band width of op-amp

- فى هذا الجزء سوف نتعرف على تأثير ال feed back (F.B) على قيمة كل من ال Band width & voltage Gain
- ولكن قبل دراسة استجابة الدواير لل F.B (دراسة تأثير ال F.B على BW & Gain) لابد من معرفة الخاصية المميزة لل op-amp

كل دواير ال op-amp تعمل كأنها LPF

low pass filter

حيث تقوم بتكبير range من الترددات الصغيرة وهى الاشارات ال dc حتى تصل الى قيمة (Cut off frequency $\omega = \omega_c$) فهى تحتوى على single pole

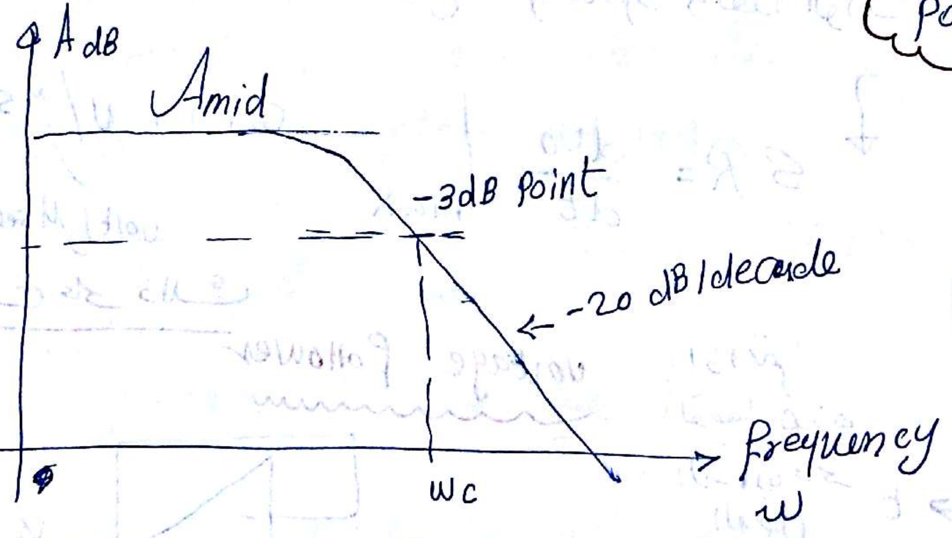
Note

$H(\omega) = \frac{S - \dots}{S - \dots}$

اصفار البسط تسمى zero

اصفار المقام تسمى pole

★ ال Transfer Function الخاصة ب LPF على الشكل التالى



Transfer function هى الدالة الى توصف العملية الى بيقوم بيها ال LPF

وعلشان نمثل ذلك بالعلاقة التالية

$$A(s) = \frac{A_{mid}\,\omega_c}{s+\omega_c} = \frac{\omega_T}{s+\omega_c}$$

اصفار المقام تسمى ← Pole

$s + \omega_c = 0$

$s = -\omega_c$

عدد ال poles الى فى ال Transfer funct. يحدد درجة ال filter

#poles = 1 → 1st order

#pole = 2 → 2nd order

∴ هذه الدالة لها single pole ← 1st order LPF ∴

A_{mid} : is the open loop Gain at dc
w_c : is the " " bandwidth of the op-amp
w_T : Called unity Gain frequency
↳ or The frequency at which $|A(jw)| = 1$ (0dB)
$20 \log 1 = 0dB$

$S = jw$

$$\therefore A(s) = \frac{A_{mid}\, w_c}{jw + w_c} \div \frac{w_c}{w_c} = \frac{A_{mid}}{1 + j\frac{w}{w_c}}$$

$$|A(s)| = \frac{A_{vmid}}{\sqrt{1 + (\frac{w}{w_c})^2}}$$

→ if $w \lll w_c$ $\quad A(s) \xrightarrow{\simeq} A_{vmid}$ #

→ if $w \ggg w_c$ $\quad A(s) = \dfrac{A_{vmid}}{\sqrt{1 + (\frac{w}{w_c})^2}}$

↑ نهمله بالنسبة $(\frac{w}{w_c})^2$

$$A(s) = \frac{A_{vmid}}{\frac{w}{w_c}} \quad \#$$

* $A_{vmid} \times w_c = w_T$

or
$$\boxed{\begin{array}{l} |A(jw)| \cdot w = w_T \\ |A(jw)| \cdot f = f_T \end{array}}$$
→ refered as GBW
gain Band width product

if gain ↑ → BW ↓ → حتى يظل حاصل الضرب ثابت & والعكس

مهم جداً at $w \gg w_c$
The product of the magnitude of amplifier Gain and frequency (w) has a Constant value equal to unity Gain frequency (w_T)

Note
$$H(w) = \frac{(s-a)(s-b)}{(s-c)(s+d)}$$

module ↓ الـ
معيف

دي الدالة اللي بتبين الـ module ده
او الجهاز ده بيعمل ايه للاشارات
الـ ~~الداخله~~ داخله ليه عشان يطلع الخرج

$X(w)$ → [$H(w)$] → $Y(w)$
الدخل الخرج

اصفار هذه الدالة
→ pole
→ zero

وهي اصفار المقام
$s - c = 0$ $\boxed{s = c}$
$s + d = 0$ $\boxed{s = -d}$
# of poles = 2

وهي اصفار البسط
$s - a = 0$ $\boxed{s = a}$
$s - b = 0$ $\boxed{s = b}$
# of zeros = 2

* عدد الـ Poles مهم جداً لان منها بحدد الـ order بتاع الـ Filter

# of Pole = 2 $\quad$ # of Pole = 1
∴ 2nd order LPF $\quad$ 1st order LPF

Frequency response of non inverting op amp "non ideal"

$A_v = \frac{A}{1+A\beta}$ $\beta_1 = \frac{R_1}{R_1+R_2}$

$A(s) = \frac{A_{vmid}\,w_c}{s+w_c}$

$\rightarrow A_v(s) = \frac{\frac{A_{mid}\,w_c}{s+w_c}}{1+\left(\frac{A_{mid}\,w_c}{s+w_c}\right)\beta} = \frac{A_{mid}\,w_c}{s+\boxed{w_c+\beta A_{mid}\,w_c}}$

deviding by $(1+A_{mid}\,\beta)\cdot w_c$

$A_v(s) = \frac{\frac{A_{mid}}{1+A_{mid}\,\beta}}{\frac{s}{(1+A_{mid}\,\beta)w_c}+1} = \frac{A_v(0)}{\frac{s}{w_{c_u}}+1} \rightarrow A(0) = \frac{A_{mid}}{1+A_{mid}B}$ $\quad s=0,\ w=0$

w_{c_u} : upper cutoff frequency $= w_c\,(1+A_{mid}\,\beta)$

w_T : unity Gain frequency $= w_c\,A_{mid}$

$\therefore w_{cu} = \frac{w_T}{A_{mid}}\,(1+A_{mid}\,\beta) = w_T\,\frac{1+A_{mid}\,\beta}{A_{mid}} = \frac{w_T}{A_v(0)}$ #

$\longrightarrow A_v(0) = \frac{A_{mid}}{1+\beta A_{mid}}$ #

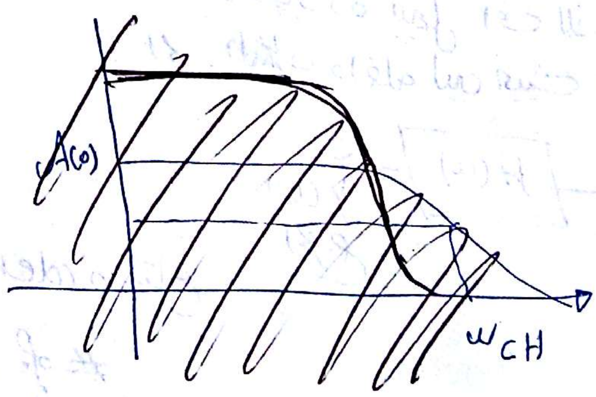
- $A_{mid}\,\beta \ggg 1$ $\quad A_v(0) = \frac{A_{mid}}{\beta A_{mid}} \simeq \frac{1}{\beta}$ & $w_{c_u} = w_T\,\beta$

  $\forall$ at frequencies which $|A(jw)| \gg 1$

  $A_v(s) = \frac{1}{\beta}$ Constant value

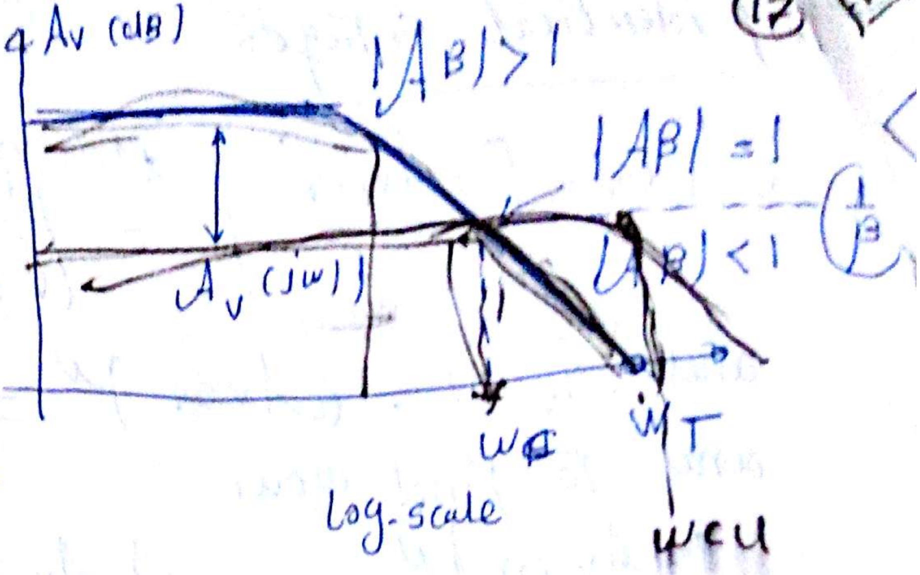
- $A_{vmid}\,\beta \lll 1$ or frequencies for $|A(jw)| \lll 1$

  $A_v = A(jw)$



F.B وهو ده تأثير ال dc gain ال اضبع

$$A_{vo} = \frac{A_{vmid}}{\beta A_{vmid} + 1}$$



نلاحظ من القوانين السابقة ان دائرة ال non inverting هي عبارة عن one pole

ولكن قيمتها تغيرت عن ال open loop بمقدار $\frac{\omega_T}{A_{vo}}$

وكذلك ال dc gain

$$A_{vo} = \frac{A_{vmid}}{\beta A_{vmid} + 1}$$

Note $A_{mid}\beta \gg 1$

$$A_v(0) = \frac{1}{\beta}$$

$$\boxed{\omega_{cu} = \frac{\omega_T}{A_v(0)} \qquad A_v(0) = \frac{A_{mid}}{1 + \beta A_{mid}}}$$

⊛ Frequency response of non ideal inverting op-amp

$$A_v(s) = -\frac{R_2}{R_1} \frac{A(s)}{1 + A(s)\beta}$$

$$A(s) = \frac{A_{mid}\, \omega_c}{s + \omega_c}$$

$$A_v(s) = -\left(\frac{R_2}{R_1}\right) \frac{\frac{A_{vmid}\beta}{1 + A_{mid}\beta}}{1 + \frac{s}{\omega_c(1 + \beta A_{mid})}}$$

نفس الخطوات بالضبط بس المقارده زيادة

⊛ Frequency response of Cascode Amplifier

$$A_v(s) = \frac{V_{oN}(s)}{V_s(s)} = \frac{V_{o1}}{V_s} \frac{V_{o2}}{V_s} \cdots \frac{V_{oN}}{V_s} = A_{v_1}(s) \cdot A_{v_2}(s) \cdots A_{v_N}$$

$$A_v(s) = \frac{A_{v_1}(0)}{1 + \frac{s}{\omega_{cu1}}} * \frac{A_{v_2}(0)}{1 + \frac{s}{\omega_{cu2}}} \cdots * \frac{A_{v_N}(0)}{1 + \frac{s}{\omega_{cuN}}}$$

∘ at low frequency $s = 0$ $\quad A_v(0) = A_{v_1}(0) \cdot A_{v_2}(0) \cdots A_{v_N}(0)$

* if identical stages

$$A_v(s) = \left[\frac{A_{v_1}(s)}{1+\frac{s}{\omega_{cu_1}}}\right]^N = \frac{\left(A_{v_1}(0)\right)^N}{\left(1+\frac{s}{\omega_{cu_1}}\right)^N} \#$$

and $A_v(0) = \left(A_{v}(0)\right)^N \#$

and to find ω_{cu_1}

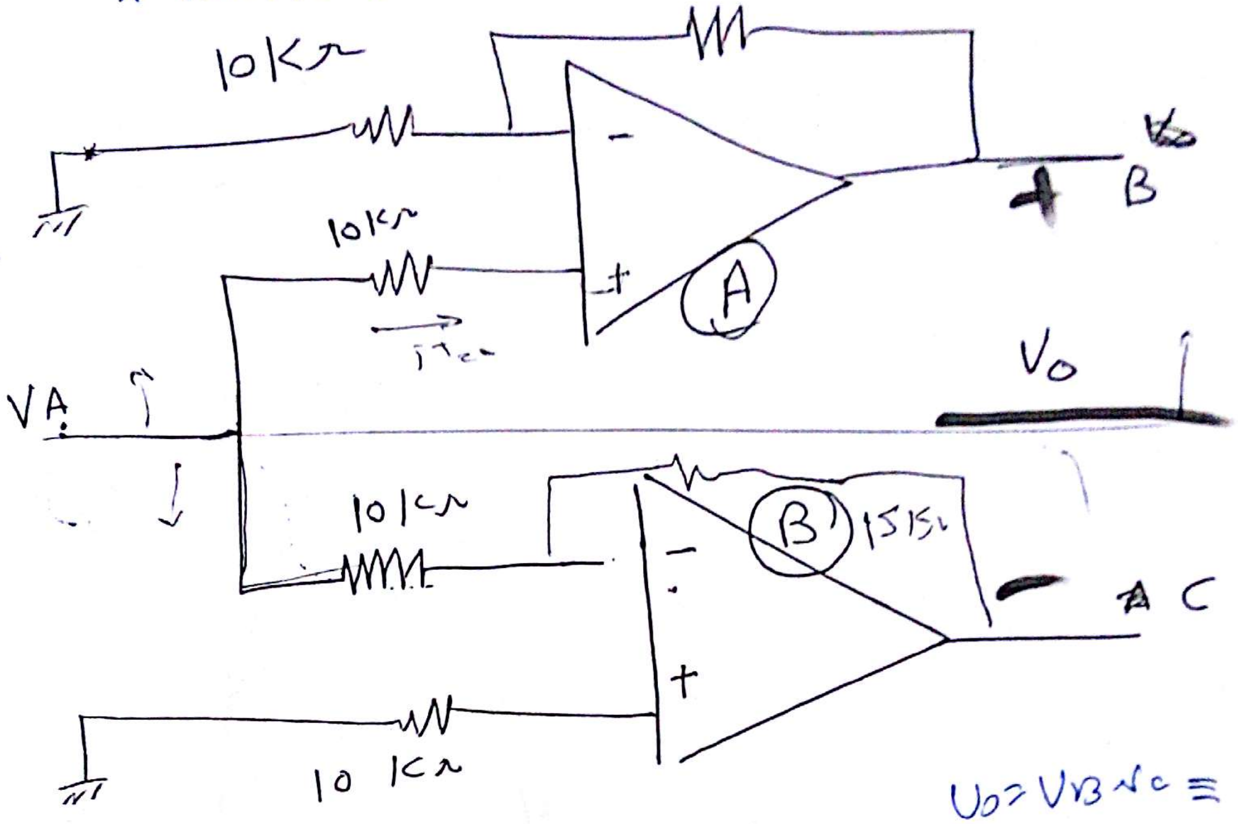
$$\frac{|A_{v_1}(0)|^N}{\left(\sqrt{1+\left(\frac{\omega_{cu}}{\omega_{cu_1}}\right)^2}\right)^N} = \frac{|A_{v_1}(0)|^N}{\sqrt{2}}$$

مش ح الحاجة الغرم

$$\boxed{\begin{aligned} \omega_{cu} &= \omega_{cu_1}\sqrt{2^{\frac{1}{N}}-1} \\ f_{cu} &= f_{cu_1}\sqrt{2^{1/N}-1} \end{aligned}} \#$$

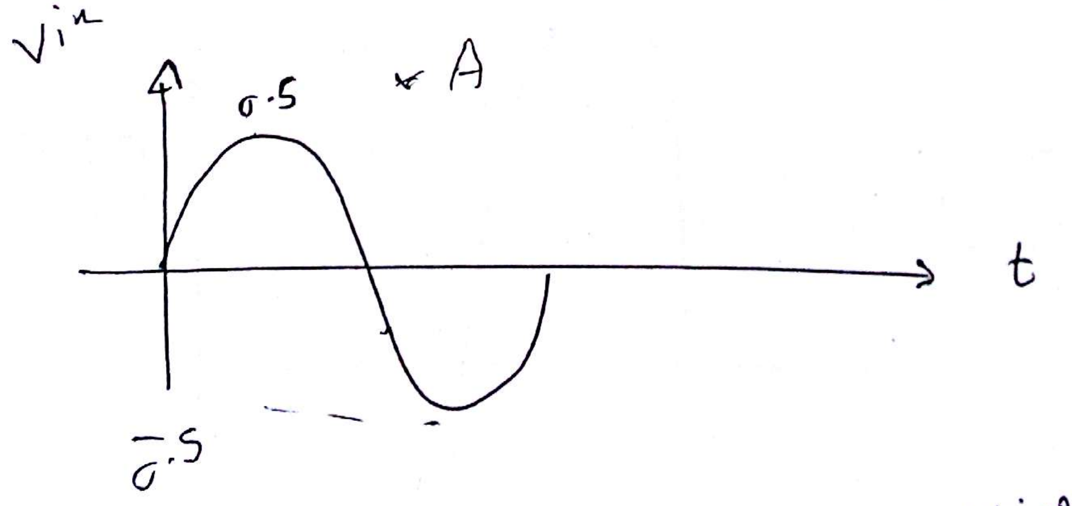
P-65

* Frequency Response
* offset Voltage
* non ideal



$U_o = V_B - V_C \equiv$

VB , Vc : 1 V Peak-To-Peak sinwave



for op-Amp A non inverting

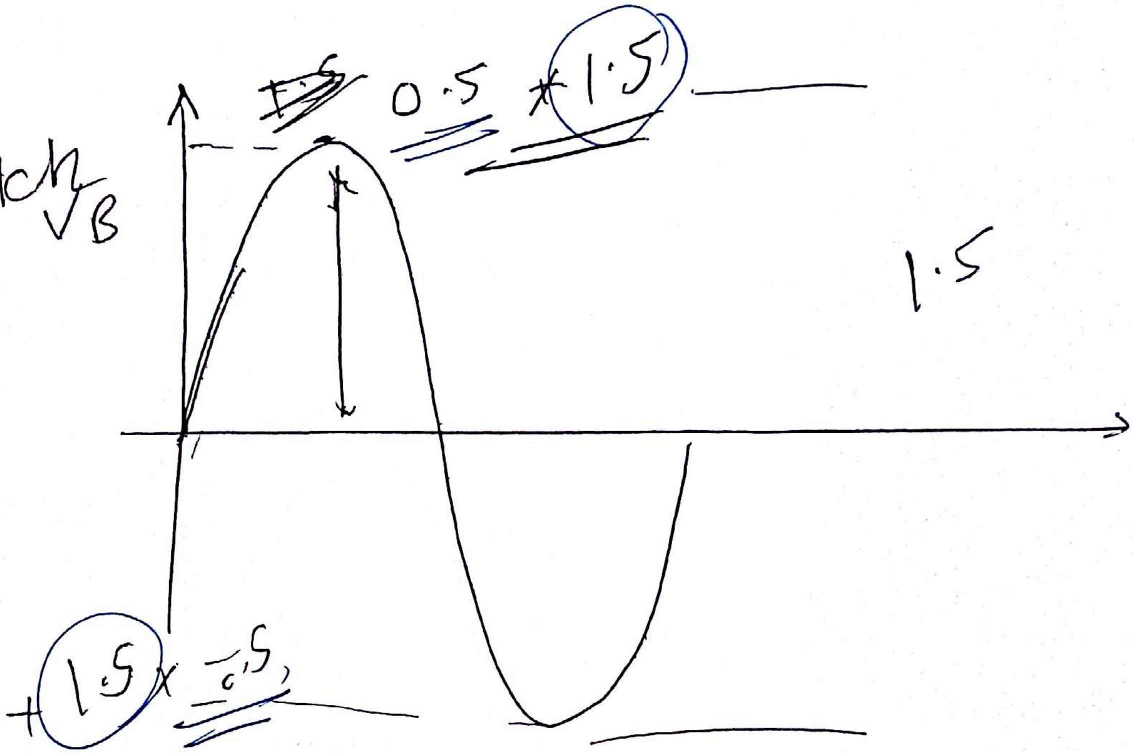
$$V_o = \left(1 + \frac{5}{10}\right) V_A$$

$$V_B = 1.5\ V_A$$

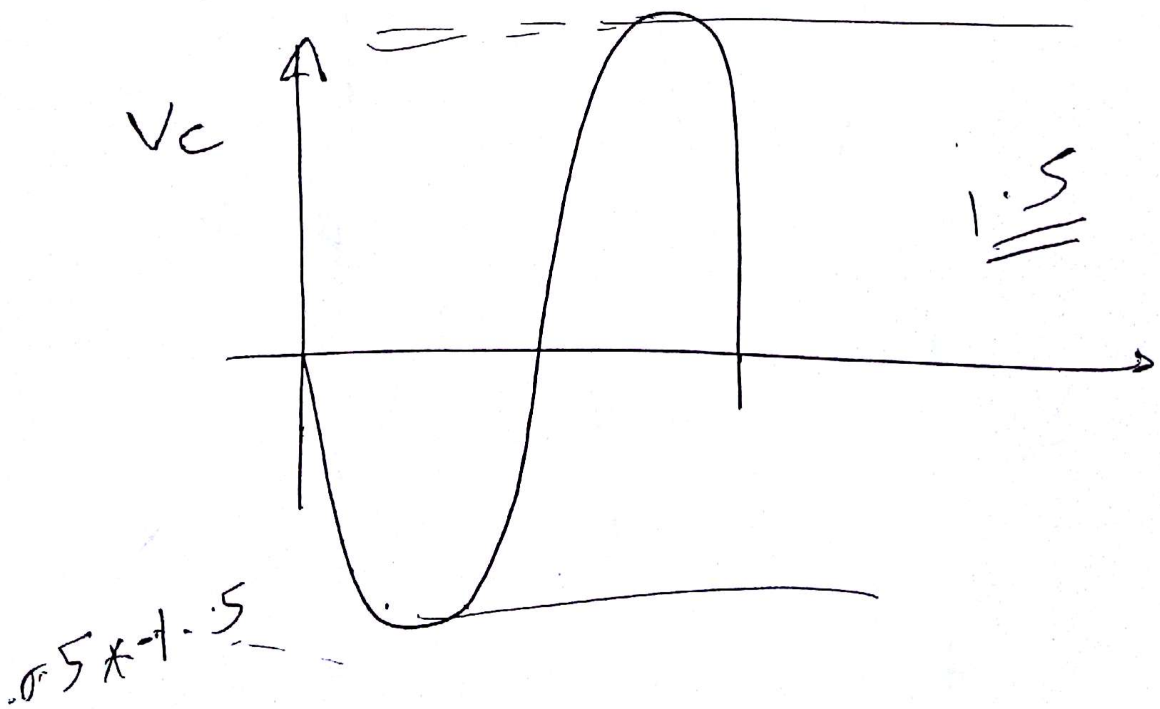
for B inverting

$V_o = -\frac{15k}{10k\Omega} V_a = \boxed{-1.5} V_a$

sketch V_B

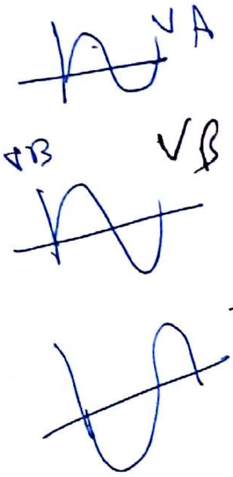


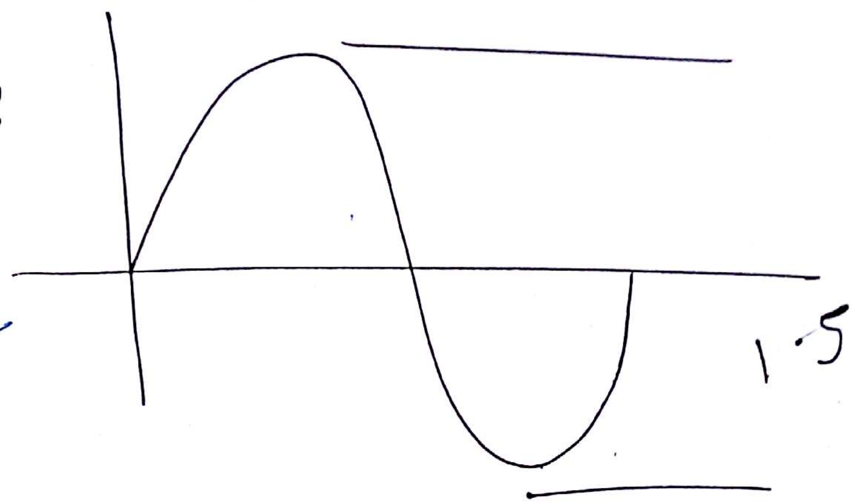
V_C

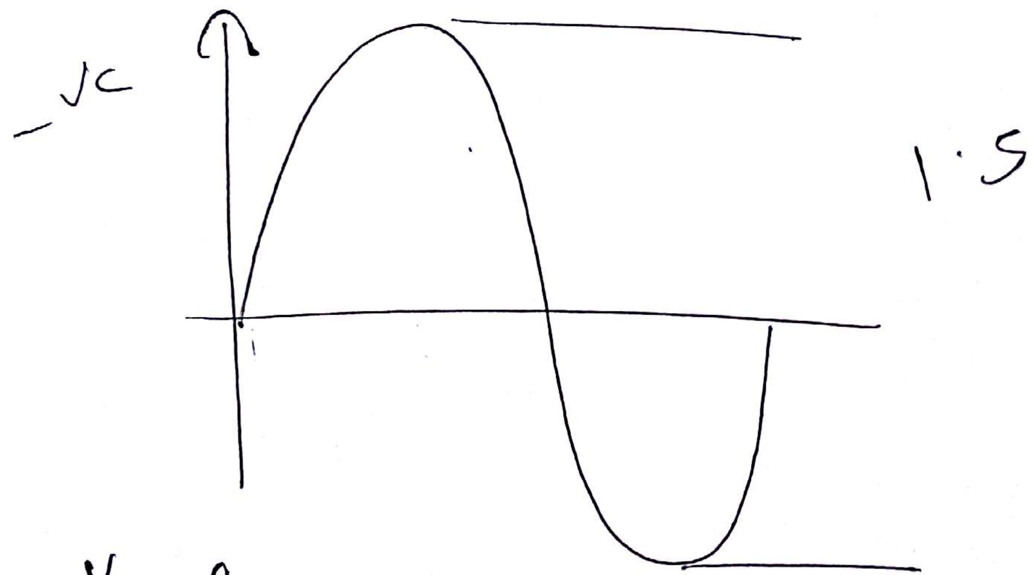


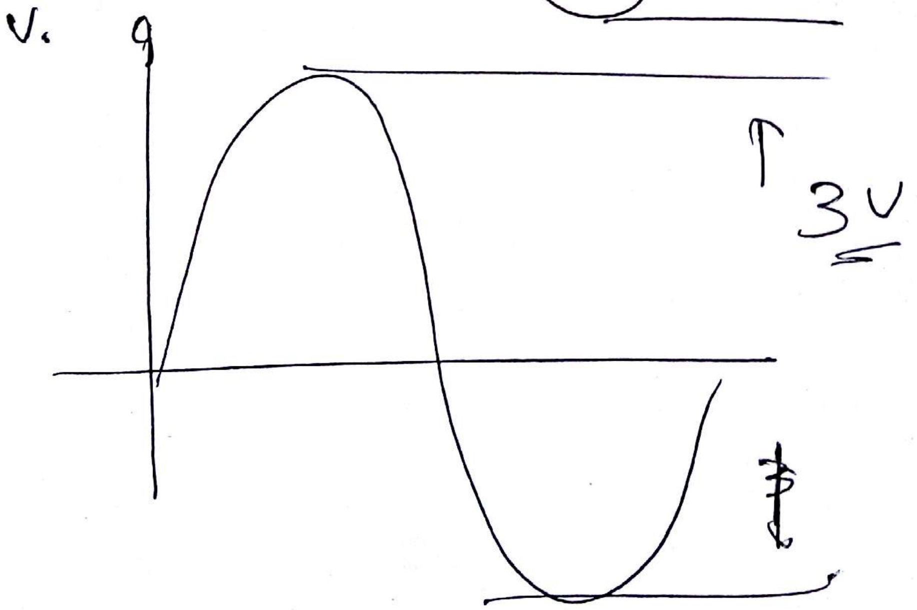
$$A_v = \frac{v_o}{v_{in}} =$$

$$V_o = V_B - V_C = V_B + (-V_C)$$







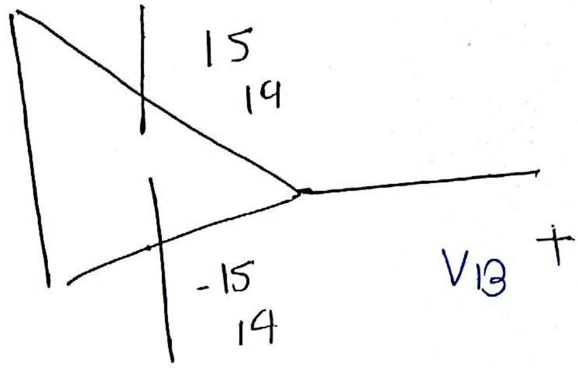


~~Vo~~

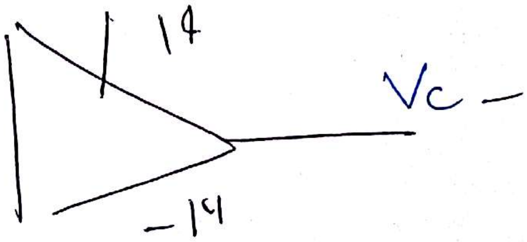
$$A_v = \frac{v_o}{V_{in}} = \frac{3}{1V} = \boxed{3\ V/V}$$

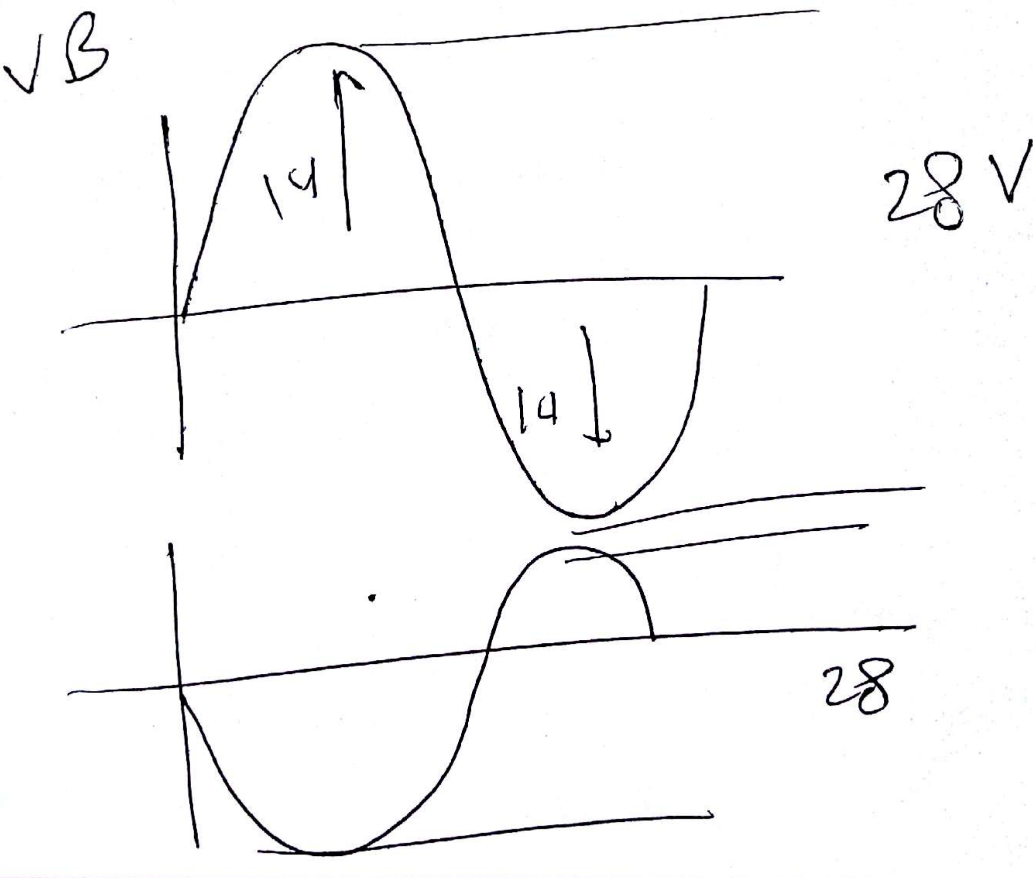
$v_o \rightarrow 3V\ p.p$

$V_{in} \rightarrow 1V\ p\text{-}p$

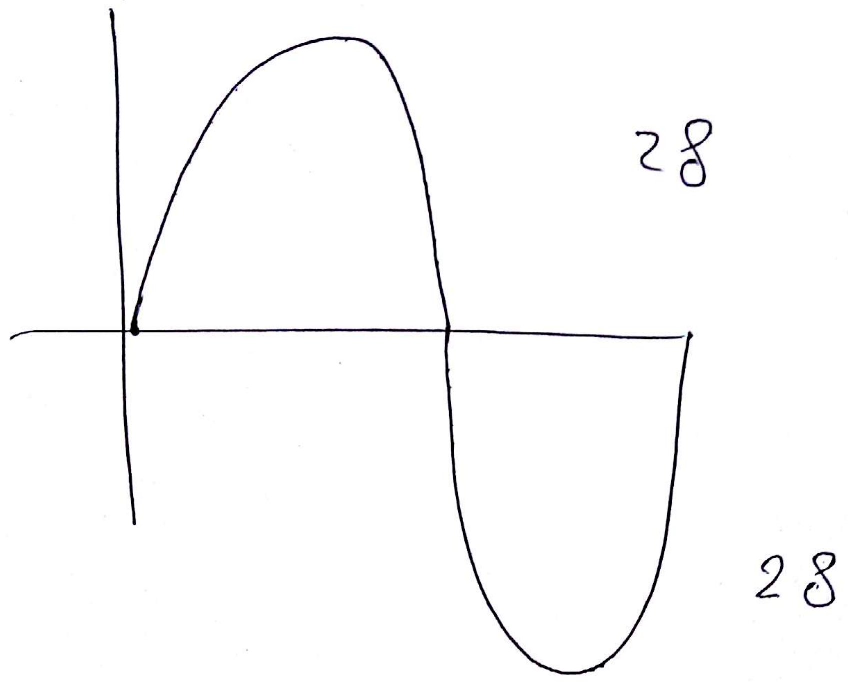


v_o



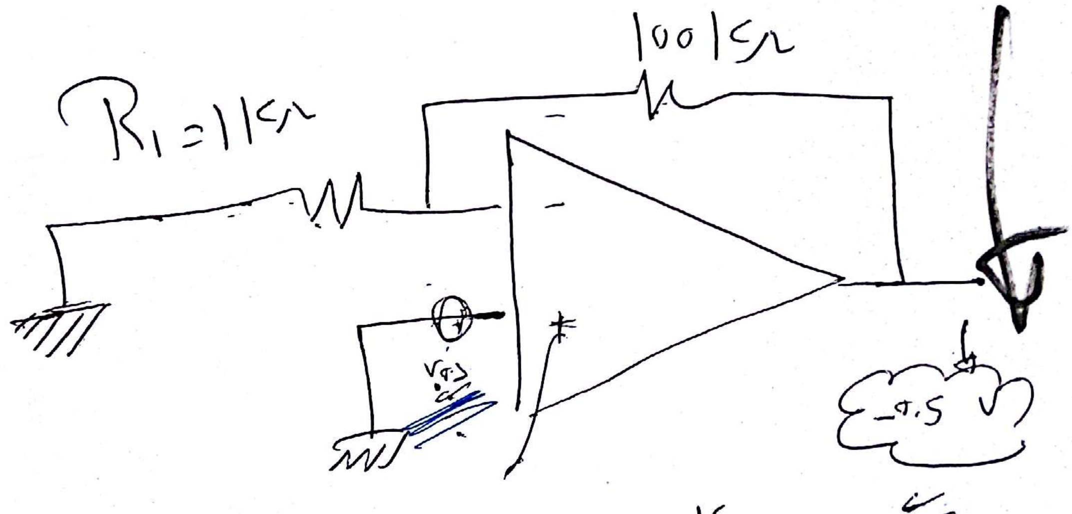


$V_o = V_B - V_C = V_B + (-V_C)$



V_o

85



-0.5

V_{os}

$$V_{os} = \left[1 + \frac{R_2}{R_1}\right] V_{os}$$

$R_2 = 100\,k$, $R_1 = 1\,k\Omega$

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gain = 100 , V_{os} ± = 2 mV

V_{in} = 0.01 sin ωt = ?? V_{out}

$V_{out} = V'_{out} + V''_{out}$

V'_{out} due i/P

V''_{out} due To offset

$V_{in} \times A = 100 \times 0.01 \sin \omega t$

$V_{os} \times A$

$2 \times 10^{-3} \times 100$

$= \underbrace{1 \sin \omega t}_{ac} + \underbrace{2 \times 10^{-3} \times 100}_{dc}$

= +

=

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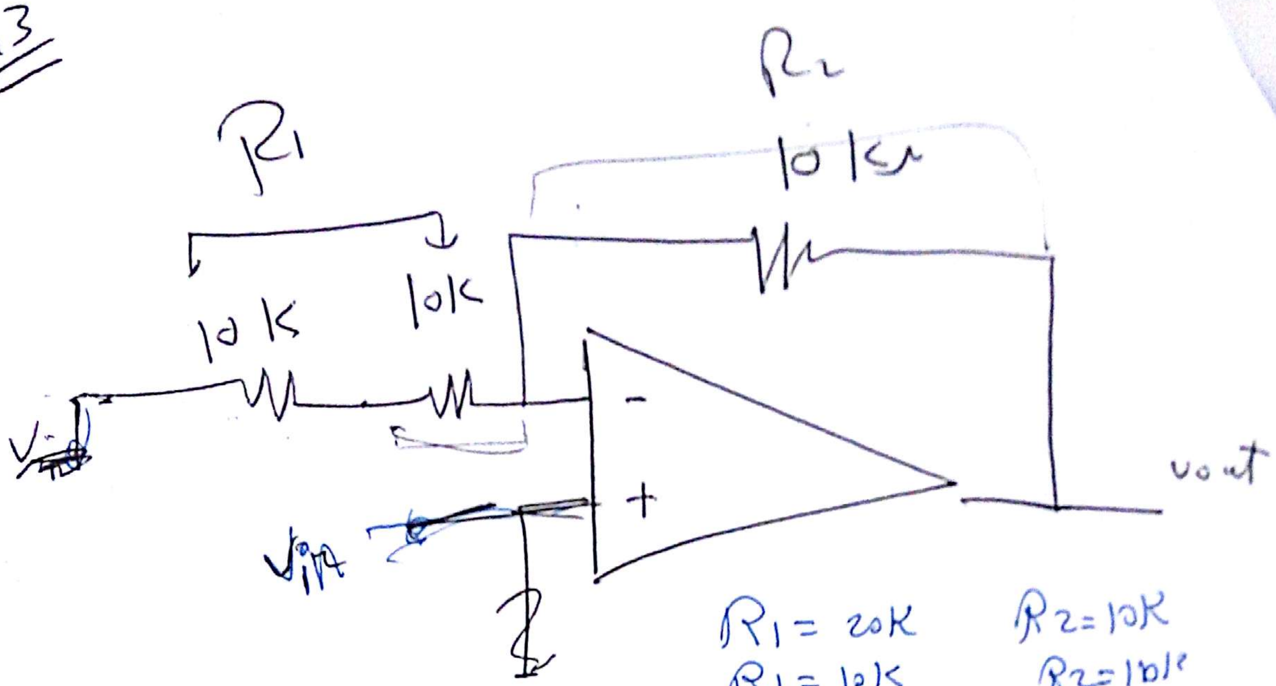


$R_1 = 20K$ $R_2 = 10K$

$R_1 = 10K$ $R_2 = 10K$

$R_1 = 10K$ $R_2 = 0$

$$A = \left[1 + \frac{10}{20}\right] = \underline{\underline{1.5}}$$

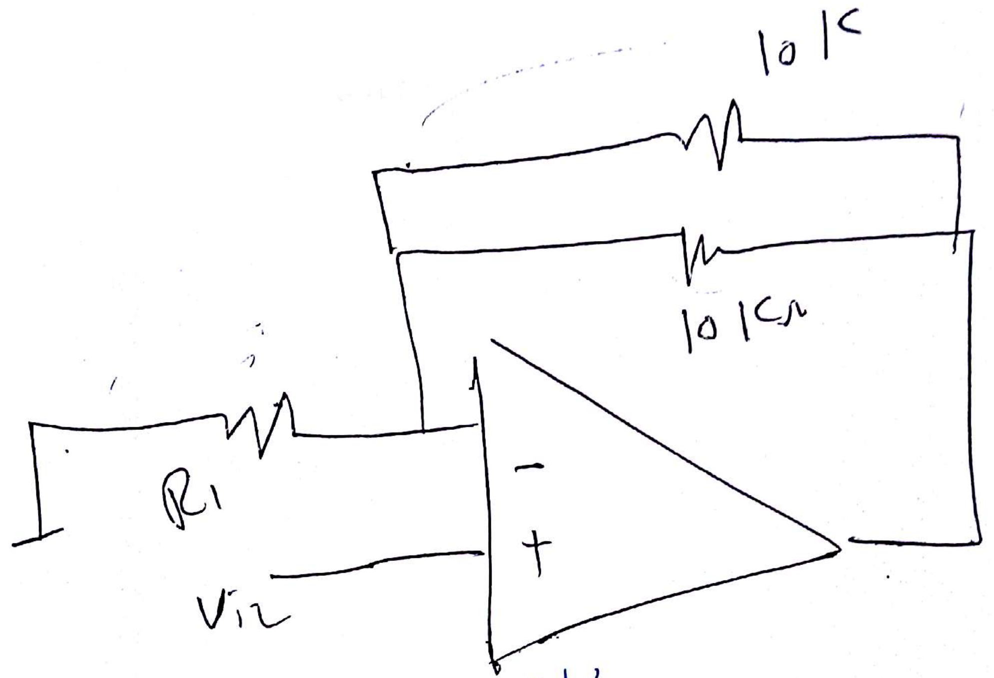
Gain ≥ 1

$$A = \left\{1 + \frac{R_2}{R_1}\right\}$$

$$= \left\{1 + \frac{10k}{10k}\right\}$$

$$= 2$$

$$A = \left[1 + \frac{\cancel{R_2}^{0}}{R_1}\right] = \boxed{1}$$



$R_2 = 10k \| 10k = 5K$

$$= \left[1 + \frac{5}{10}\right] = 1.5$$